

# The Blast Furnace *and* Steel Plant

## Data for Shearing Steel and Other Metals

Tests to Determine the Equivalent Cutting Capacity of Given Shears on Various Kinds of Stock—Curves Presented Obtained from Series of Practical Shearings.

By W. TRINKS.

Alligator shears and bar shears are usually designed and sold for cutting mild steel. Quite frequently the builders of such shears are requested to furnish information on the equivalent cutting capacity of such shears for cutting brass or copper, and just as often second hand shears are bought for this purpose. The safe cutting capacity of the shear, both with regard to the strength of the shear and to size of motor, is usually guessed at. Sometimes the guess is good, more often it is bad.

In order to do away with this guessing, the author undertook to make tests on the shearing strength of different metals. These tests were made on a 100,000-lb. Olsen testing machine at Carnegie Institute of Technology\* with a double shear tool, a sketch of which is given in Fig. 1. It will be noticed that the outer ends of the sheared bar are not prevented from rising, so that the test conditions approach those actually found in practical shears. The sheared sections were  $\frac{3}{4}$  in. by  $\frac{3}{4}$  in. and 1 in. by 1 in. A very slow motion of the head was employed, in order to get stationary readings. The penetration of the upper knife, or, what is the same, the approach of the two cutting edges was measured simultaneously with two deflectometers.

The results of the tests are shown in the nest of curves, Fig. 2. The abscissae are the penetration ratio, which is the ratio of depth of cut to original thickness. If this ratio for instance is 0.5, each of the knife edges has sunk  $\frac{1}{4}$  of the original thickness into the material. The ordinates are shearing stresses, in pounds per square inch of original section. Taking for instance curve 1, we find that the maximum stress of 53,000 pounds per square inch is reached, when the knife edges have come together about 11 per cent of the original thickness. If the section to be cut is 5 in. by 5 in., then the force required will be  $25 \times 53,000 = 1,325,000$  pounds.

Evidently, the maximum stress varies greatly with the material, ranging from about 20,000 pounds per

square inch for copper to about 53,000 pounds per square inch for cold rolled steel.

The area under the curve from the origin to the breaking point is a measure of the work which must be done in cutting the material. Take for instance curve (2), for mild steel. The maximum value of the shear is 47,000 pounds per square inch, depth of penetration at shearing point is 0.34 of the original thickness. The average stress over this depth is roughly  $\frac{2}{3} \times 47,000$  or 31,000 pounds per square inch. Then the work done in cutting a 5 in. by 5 in. bar of mild

steel is  $5 \times 5 \times 31,000$  (pounds)  $\times \frac{34 \times 5}{12}$  (feet) = 110,000 ft. pounds. Overly great accuracy is not re-

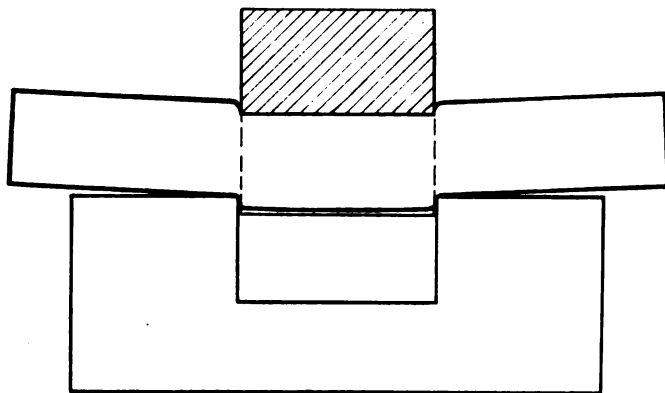


Figure 1.—Scheme for Shearing.

quired in this calculation, because the nature of the material to be cut is seldom definitely known. It is interesting to know that, while mild steel, curve (2), and copper, curve (4), require very different shearing forces for the same cross-section, the amount of work required for shearing is almost the same for both materials.

In practice, shearing forces are higher than the curves of Fig. 2 indicate, because shearing in practice is done at considerable speed. The stresses shown in Fig. 2 are "no speed" stresses, or the minimum values which can ever be encountered. To them must be

\*Tests and calculations were made by J. D. Keller.

added the stresses arising from internal friction. Making the crystals slip over each other against molecular cohesion requires additional stress, the magnitude of which depends upon the velocity of deformation. The amount of this stress is at present not definitely known to the author, but may, from experiments on other deformations of metals, be taken to be 10 to 20 per cent of the no speed stress. Consequently the forces required in practice may be expected to be the given amount rather than those computed from the curves.

If the shearing strength, as taken from Fig. 2, is

compared to the tensile strength, it is found that the former is about 60 to 68 per cent of the latter. This relation may be made use of the shearing of metals for which no test data exist. If not even tensile strength data are available, the Brinell hardness may be used as a rough guide. For the metals investigated in the present tests, the hardness numbers are given in Fig. 2.

Those readers who studied mechanics of materials may remember that the shearing strength of metals was, by theory, expected to be 80 per cent of the tensile strength. According to a later theory, developed by

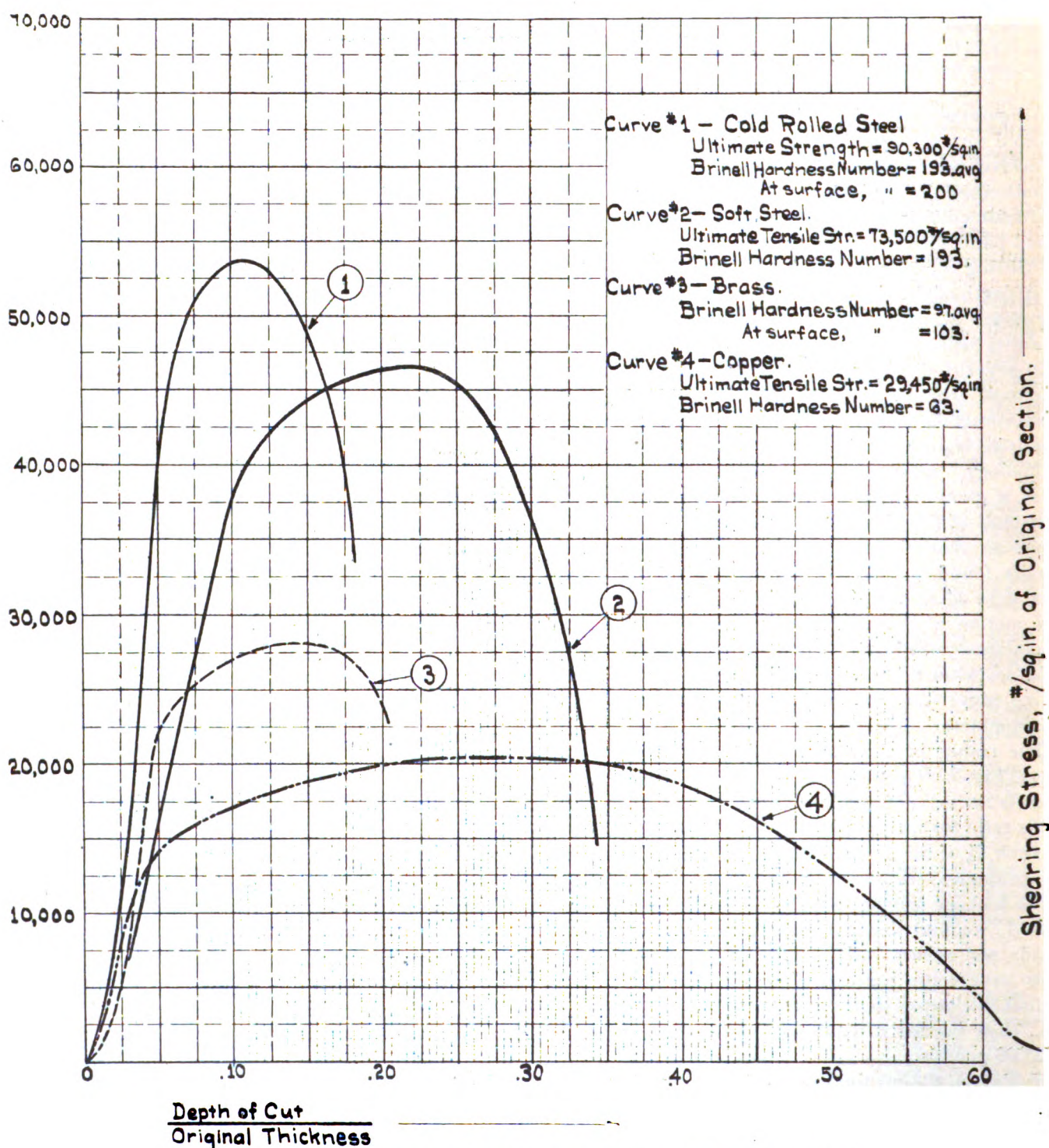


Figure 2.—Shearing curves and work required for steel and other metals.



Mohr and Guest, it may be expected to be 50 per cent of the tensile strength. While either one or the other theory may be correct, if the stresses are referred to the final sections (both in tension and shear), the ratio of shearing strength to tensile strength, if the stresses

are referred to the initial sections is right midway between the values given by the two theories, namely

$$\frac{.8 + .5}{2} = 0.65.$$

# Manganese Significance in Steel Metallurgy

Taking Up the Value of This Element as a Necessity in Steel-Making—Showing Some of the Many Uses for This Alloying and Purifying Material.

By F. H. WILLCOX, Metallurgical Engineer, U. S. Bureau of Mines.

In Bessemer-steel practice, air is blown through a bath of iron, or projected strongly upon its surface to burn out silicon, manganese, and carbon. Toward the end of the blow, when the iron is not protected from oxidation by these elements and the excess of air becomes great, there is oxidation of the iron. In open-hearth practice, the same difficulty is experienced with dissolved gas and oxides in the product, though not to as great or severe a degree as in the Bessemer process because the oxidizing conditions grow less severe as the end of the heat is approached, and if the bath is allowed to boil for a time it undoubtedly frees itself from a large part of the gas and oxides which have been absorbed in the earlier part of the process. Basic open-hearth steel is usually assumed to contain a larger proportion of oxides than acid open-hearth steel, but it may be said that all steel, Bessemer and open-hearth, contains more or less oxide of iron dissolved in the fluid metal at the end of the "blow" or "heat."

That certain metals are solvents for their respective oxides has been shown, in the case of copper, by Heyn, and, in the case of iron, by Law. It is indicated that the solubility of iron oxide in iron increases with the purity and temperature of the metal. This confirms what is observed and known by operating men, and these observations may be summarized as follows:

1—Cast iron is rarely subject to oxidation, as is logical from its composition.

2—Normal steel, unless deoxidizers are added, contains blow holes.

4—The addition of deoxidizers prevents, to a greater or less degree, the formation of blow holes in normal steel.

With these observations in mind, it is logical to deduce that the cause of blow holes lies in part in the presence of dissolved oxide of iron in the molten steel and its consequent reaction with the carbon of re-carburizers, when these are added, to form gases. (Another factor in the origin of blow holes is, of

course, the solubility of gases themselves in the steel and their consequent separation when the metal solidifies in cooling.) In addition to the propensity of dissolved oxides to form blow holes in the steel they are harmful in that they produce brittleness in the steel. Also, oxides are at present under suspicion in that they are believed to promote corrosion.

To produce a dense homogeneous steel, free from honeycombing, there is required above all the removal or suppression of gases; occluded, dissolved or mechanically held. To prevent dissolved gases, or gases formed as a reaction product from separating out at solidification, fluid compression and hot tops have been employed. But average practice is more concerned with the removal or suppression of gases before solidification. The wilder the metal (i. e., the more gases evolved) the more boiling there is and, consequently, the more segregation and blow holes, so that, in extreme cases, the ingot is absolutely unfit for use. Hand in hand with the necessity for removal or solution of dissolved gases is the necessity for reducing the iron-oxide dissolved in the steel, because, apart from any probable detrimental effect of the oxide as such, there is the probability of the formation of carbon monoxide or dioxide by the reaction of the iron oxide with carbon. Whether these ends are met by the direct elimination of the gases and oxides, or by their elimination as compounds of the deoxidizer used, or by increased solvent power of the steel for gases, is perhaps immaterial solely from the viewpoint of structural density of the solid product, however important it may be from the viewpoint of immunity from corrosion or gain in dynamic properties. These last two points must be considered when the matter of deoxidizer additions is under consideration, but the purpose of this paper and its length permit only consideration of the value of deoxidizers from the standpoint of removal of gases and oxides.

## Materials Used as Deoxidizers.

Manganese.—It may be fairly said that the basis of modern steel making lies in the several functions of manganese alloys when added to a steel as carbur-

Paper before the February meeting, American Institute of Mining Engineers. Presented by permission from the director, Bureau of Mines.

izers or deoxidizers. These functions may be classified as follows:

A.—In foundry practice:

1—Its use as a deoxidizer and desulphurizer.

2—Its use to alter the constitution of grain in the metal.

B.—In steel-works practice:

Its use as a deoxidizer.

2—Its use to impart certain static properties to steel.

Ferromanganese is the most prominent and widely used of deoxidizers. Added in the form of ferromanganese or spiegeleisen, or intermediate products, manganese is readily oxidized and seizes with avidity any oxygen dissolved in the steel as oxide, this property being strong at the temperature of molten steel. For this purpose it is added in proportions varying between 0.3 or 0.4 to 1.5 per cent; below 0.3 per cent the steel is liable to be harmfully charged with oxides. The deoxidizing action is usually considered to lie in the greater affinity of manganese than of iron for oxygen, and the consequent seizing by the manganese of the greater part of the oxygen existing as dissolved oxide of iron. The manganese oxide thus formed is insoluble in iron and goes almost entirely into the slag, returning iron to the bath as metal. The usual additions of manganese do not entirely eliminate oxygen from the steel, and probably have a small effect upon dissolved gases. Traces of oxygen are commonly taken care of by the addition of aluminum after the ferromanganese addition, but the scavenging effect of manganese is nevertheless very strong, and it is this action, in addition to the other functions, that makes its use so indispensable. Another action of manganese, to which is due in part its value, is its behavior with sulphur. As steel exists at the end of a "blow" or "heat," the sulphur is present almost entirely as sulphide of iron. Microscopic examination shows iron sulphide to exist in steel largely as films between the metallic crystals, a condition which gives rise to weakness and brittleness of the metal when hot—"red shortness," due to the impairing of the closeness of texture and cohesion of the iron molecules. Manganese additions convert the iron sulphide to mixed sulphides. With the present low sulphur specifications and fast practice, it may be doubted whether very much manganese sulphide separates out from the metal into the slag. It probably remains in very large part in the metal, but is found to exist as sharp or rounded inclusions instead of films. A third property of manganese, which is lacking in the more common deoxidizers to be mentioned, is that it raises the critical temperature to which it is safe to heat the steel, preventing coarse crystallization at high temperatures.

Aluminum—Aluminum possesses to a high degree the ability to remove traces of oxygen from steel, very small quantities, about 0.05 per cent, "killing"

the steel. In itself, it is a more efficient deoxidizer than manganese or silicon, but when considered as the sole means of deoxidizing the steel rather than as an ingredient to be used for removing the last traces of gases, there are objections to its use. First, the product of reaction, alumina, is a relatively infusible product, its melting point being higher than the usual temperature of steel, and it may therefore chill and remain suspended in the metal instead of coalescing and floating or separating out into the slag. If used in a large amount, therefore, it may give rise to a dirty steel and render the mechanical properties weaker on account of the presence of non-metallic impurities. Second, alumina is incapable of eliminating or changing the condition of sulphur, as does manganese. Third, the use of too much aluminum introduces a tendency to form a larger pipe. Aluminum is without question beneficial when used rationally, for several reasons: The heat of reaction is appreciable and possibly renders the steel more fluid momentarily; by "killing" the steel, the metal is quiet and crystallization of the type described as "land locking" or "pine tree" is encouraged, thus decreasing segregation; and because aluminum seems to increase the solvent power of steel for gases, its use prevents blow holes to a marked degree. The point to be carried in mind is the natural limitation of aluminum as a total substitute for ferromanganese.

Silicon.—Ferrosilicon is effective for removing dissolved oxygen, even when added in proportions as small as from 0.1 to 0.2 per cent by weight of the steel. It reduces honeycombing, is said to diminish segregation and to increase the solvent power of the metal for gases. A large pipe is formed in ingots when ferrosilicon is used in excess. Another drawback is that the products of oxidation may remain in the steel should the reaction end product be silica rather than a silicate. Analyses do not show whether the silicon is present in the metal, as a result of additions, as a silicate, silica, or a silicide. Silicon additions have no effect in eliminating red shortness caused by sulphur, or molecular derangements of the metal, to compare with the effectiveness of manganese. An experiment is recorded where ferromanganese was reduced by 50 per cent and ferrosilicon increased in varying percentages in an endeavor to economize in the cost of manganese additions, but with the result that the metal was honeycombed and permeated with inclusions of slag. Ferrosilicon finds its most effective use in the foundry rather than in the steel works.

Titanium—Ferrotitanium is given an excellent rating as a deoxidizer by some authorities, but is far from recommended by others. It is said to increase ductility, to prevent honeycombing and segregation, and to remove both dissolved oxygen and nitrogen. The removal of nitrogen is probably without question, and since the removal of all gases is necessary to obtain sound steel, there is no doubt of the worth of an



element that will remove nitrogen. Titanium does not freely alloy with iron, but is more likely to be found as microscopic inclusions in the form of nitride or carbide. When used alone, it is not as effective a deoxidizer, as when used with ferromanganese, to replace appreciable quantities of the latter. With ferrotitanium, as with ferrosilicon and aluminum, the use of ferromanganese is usually essential to obtain a dense workable product.

Other Deoxidizers.—In addition to the above materials, many other deoxidizers have been suggested and some have been used. Among these are magnesium, calcium, sodium, vanadium, uranium, boron, and alloys of these with manganese, aluminum, silicon and titanium. These washes have as a general base the idea that the reaction product should be a slag of great fluidity so that it will coalesce into globules of sufficient size to float out of the metal. Among these deoxidizers may be mentioned calcium-silicide, ferroaluminum-silicide, ferrocadium-silicide, ferromanganese-aluminum-silicide, and ferrotitanium-aluminum-silicide. In most of these alloys the various elements reinforce each other and should make powerful deoxidizers, and be pre-eminently suitable for producing homogeneous steel. Whether they actually are suitable is not known; they are apparently playing little part in present-day practice. The extent to which thorough study of these and similar possible deoxidizers has been carried is apparently small. The importance, interest and value of experiments along these lines should be evident in view of the manganese situation in this country.

Germany has relatively scanty resources of manganese within its borders. For that reason it may be of interest to discuss briefly the apparent situation there when the Central Empires are cut off from former sources of supply. From time to time, reports have come from Germany which seem to have great technical importance. For instance, about a year ago a Dr. Schroedter mentioned, as a metallurgical experiment and secret, means by which Germany was able to get along with less manganese than formerly in steel making. Substitute alloys have been mentioned and also a method by which metallic oxides of iron are eliminated from the slag in open hearth practice before the heat is tapped, thereby freeing the steel itself of oxides. The facts in the case seem to be much as follows: In the year before the war almost twice the normal amount of high-grade manganese ore had been imported from India and Russia. Also, in the spring of 1915, it was reported that stocks of manganese ore had been confiscated at French and Belgian plants. During the last year, manganese has been reported scanty and prices have been high, though not as high as speculative dealings and scarcity have forced the price in this country. During the past year, piles of slag from old ferro-manganese furnaces in Westphalia running from 5 to 14 per cent man-

ganese, have been drawn upon, and U. S. Consul Albert, of Brunswick, Germany, reports that the village of Adensliddt has been demolished to secure manganese ore running about 22 per cent maganese. Lately, complaint is reported from Dutch sources in regard to the quality of German steel. It is said that the steel is daily proving worse and is becoming hard and brittle. The deterioration is attributed to lack of skilled workmen and to the lack of manganese.

Before the European war, little ferromanganese was produced in the United States except by one large company. The apparent reason was that supplies from abroad had always been abundant and had been offered at reasonable, and sometimes remarkably low prices, \$40 or \$45 seaboard. At the beginning of the war the price was \$68 seaboard for British ferro-manganese, and since the war it has touched over \$400 per ton. At present the price is in the neighborhood of \$165. Before the war, independent steel companies depended almost entirely upon importations and upon one large producer in America, the latter having adopted a liberal policy in sales and in tiding competitors over periods of temporary stringency. Within the last 18 months, several new producers have entered the field.

TABLE 1.—Production and Imports of Manganese Material

|                  | Production       |               |             | Imports          |                                  |
|------------------|------------------|---------------|-------------|------------------|----------------------------------|
|                  | Ferro-mang. Tons | Spiegel, Tons | Total, Tons | Ferro-mang. Tons | Apparent supply Ferro-mang. Tons |
| 1912             | 125,378          | 119,506       | 244,884     | 90,137           | 224,515                          |
| 1913             | 119,495          | 126,081       | 245,576     | 128,070          | 247,565                          |
| 1914             | 106,083          | 100,365       | 206,448     | 82,217           | 188,300                          |
| 1915             | 146,542          | 93,282        | 239,824     | 55,201           | 201,743                          |
| 1916 (estimated) | 195,605          | 181,327       | 376,932     | 73,031           | 268,636                          |

TABLE 2.—Rate of Steel Production.

|      | Open Hearth | Bessemer   | Other       | Total      |
|------|-------------|------------|-------------|------------|
| 1912 | 20,780,000  | 10,327,000 | 142,000     | 31,251,300 |
| 1913 | 21,500,000  | 9,545,000  | 155,200     | 31,300,200 |
| 1914 | 17,174,000  | 6,222,000  | 117,400     | 23,513,000 |
| 1915 | 23,670,000  | 8,287,000  | 184,000     | 32,151,000 |
| 1916 |             |            | (estimated) | 42,000,000 |

From Tables 1 and 2, it may be estimated that the average consumption of ferromanganese for the years 1912, 1913, and 1914 runs about 19 lb. per ton of steel. This is deduced by estimating that 30 per cent of the Bessemer production for these years is recarburized and deoxidized by spiegel instead of ferromanganese. Applying the same estimate to 1916, we have 360,000 tons as the indicated consumption of ferromanganese for 1916.

Such an estimate is an approximation and the indication of a deficit of 100,000 tons of ferromanganese is, of course, not borne out by the market price at the present moment. Inasmuch as the method of approximation is applicable to normal years, the apparent deficit shows that unusual economies are being exercised in the use of 80 per cent ferromanganese. Intermediate products, between 20 and 80 per cent manganese, ferrosilicon, silicospiegel and special deoxidizers are being used liberally, so that the apparent lack of ferromanganese shown in the above analysis is compensated for by these substitutes and economies. From all indications—i.e., market prices, estimates, and quality of steel—there is no danger in the present fer-

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romanganese situation in regard to a sufficient supply of the alloy. Notwithstanding this fact, the general situation regarding the supply of manganese for the country is not without disturbing features, inasmuch as we are dependent upon British alloys and upon foreign ore for this ingredient in steel making.

The production of manganese ore in the United States for the year 1915 was 9,651 tons. This was in the face of an unprecedented demand, a shortage in the supplies of foreign ore and alloy, a price per unit of manganese that reached 97 c. (the average price per unit for the preceding 5 years was 12½ c.) and following extensive exploration work. This tonnage was scattered through 10 States and came from 34 producers, and should be contrasted with our importations of foreign ores.

TABLE 3.—Imports of Manganese Ores.

|            | Tons                    |
|------------|-------------------------|
| 1914 ..... | 288,706                 |
| 1915 ..... | 206,859                 |
| 1916 ..... | 492,850 (apparent rate) |

The bulk of this foreign ore in the present year is coming from Brazil. In 1913, one-third of the ore came from Brazil whereas this year nine-tenths is coming from that country.

It is evident that we do not produce this ore in quantities commensurate with our consumption. In fact, our production is negligible; how negligible, may be realized from the fact that based upon the amount of ore necessary to furnish the apparent supply of 260,000 tons of ferromanganese available this year, our production of ore amounts to 1½ per cent. Our contribution is equivalent to about 2 per cent of the ore required to furnish the apparent production of 195,000 tons of ferromanganese in this country. This is on the basis of last year's production. This may be increased this year, but it is not possible that it can be increased to a degree commensurate with our requirements. No deposits of rich manganese ore that hold any promise of furnishing the needed quantities of this material have been developed to date in this country. The situation can not be better expressed than in the words of an editorial in a recent number of an iron trade journal: "Insecurity lurks behind these facts (apparent supply of manganese). To supply this most necessary element in making steel, our own territory has furnished scarcely any ore. The iron industry is dependent absolutely upon foreign supplies and sources for manganese, without which thus far good steel is impossible. Were war to break out between us and a first-class power capable of controlling in part or entirely the high sea, our situation would be precarious, for no nation can defend itself without steel. Assiduous efforts to discover manganese ore in this country have been unavailing. We are dangerously dependent upon manganese. It is to be hoped that metallurgical science will discover a substitute."

This situation is not one that carries immediate

danger. It is certainly comparable, however, to the potash and nitrate situation and the suggested production of these materials in this country. It may well be more serious than either of these two examples. In a national emergency we could economize and to some degree dispense with the one and manufacture the other, but we can neither entirely dispense with nor manufacture manganese, nor can we economize in its use to the degree called for by our inadequate production and great demands.

### Conclusion.

These are two ways to meet such a situation as has been presented in the above paper. The first suggestion is an obvious one, and is that the manufacturers of the country accumulate a sufficient reserve of highgrade manganese ore to tide the steel industry over at least a year's stoppage in supply. The amount of capital that would be tied up by the investment in such a tonnage of ores at the present prices and scarcity of freight-carrying bottoms is the answer to this proposal at the present time, and may be a deterring factor for all time to come, because when the present war is over and peace established, the present very apparent need of some such precaution will naturally become less and less evident. The second suggestion is that an attempt be made to develop a substitute alloy which can be used in place of or, more probably, with ferromanganese in such proportions as to conserve the manganese.

As far as can be learned, substitute deoxidizers are not playing a part commensurate with that which they would be called upon to do in case of emergency, nor are our resources of manganese in such shape, nor our means of utilizing them sufficiently developed, to enable us to count upon them in case of need. No thorough and independent study has been made of all combinations as regards their efficiency in deoxidizing steel and rendering it homogeneous and workable, either as a whole or part substitute for manganese, or if this has been done, it is not generally known and available.

Before undertaking work of this nature—which would involve preparation of many alloy combinations, coöperation with steel and foundry men, and chemical and metallographical examination of the steel treated with these alloys for inclusions of gas, oxides, and slag—it has seemed best to submit the situation and the need of investigations on substitute alloys, in order that an opinion may be expressed as to whether the matter is of sufficient importance and promise to warrant serious consideration.

The United Furnace Company, Canton, Ohio, has retained Barton R. Shover, consulting engineer, Pittsburgh, on the new power installation at the plant now building.



# Mill Designs for Rolling Flat-flanged Beams

Various Types of American Mills for Turning Out Flat-Flanged Beams—Means Adopted to Avoid Tilting and Turning of Beams and Complications Thereby Introduced.

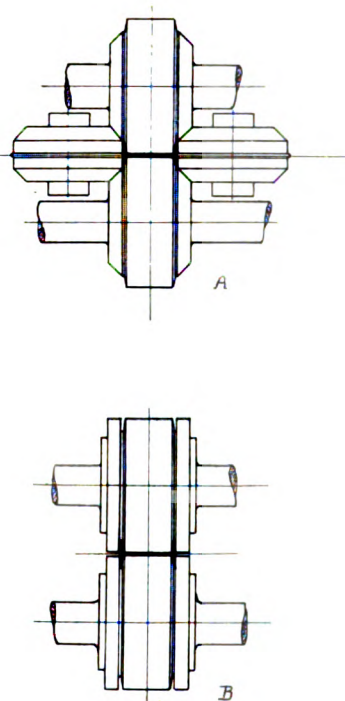
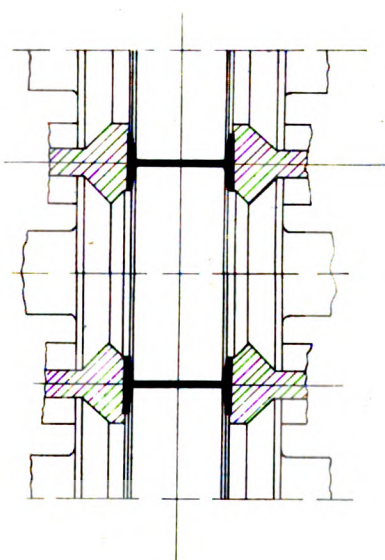
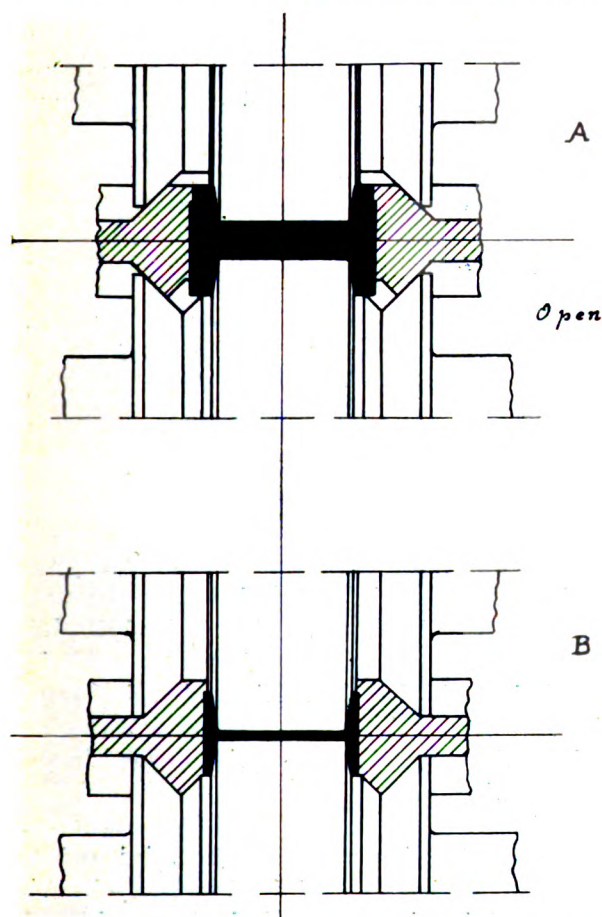
By F. DENK.

After having described the different types of Grey mills as successors of the York mill, we have to go back again to the end of the last century for further information in regard to mills for rolling wide-flanged beams.

In 1885, J. L. Seaman, Pittsburgh, Pa., obtained

bend upward or downward after leaving the rolls and they must, therefore, be straightened, either by powerful guides or by a straightening press or rolls.

Designers have tried to avoid the tilting of the beams, which means a complication of the mill, at least when the beams become long, by using a three-high



Figures 19, 20, and 21.

letters patent for a universal reversing mill for rolling wide-flanged beams. The beam entered the rolls in a rough H-shape (see Fig. 18, A) and was rolled down to the final section (see Fig. 18, B) in one stand. The axes of the two pairs of rolls are all lying in the same vertical plane, the two horizontal rolls being unlike to each other but individually symmetrical, while the vertical rolls are both alike, but individually unsymmetrical. The beam must be turned 180 deg., i. e., half round, after each pass, as was the case with the Sack mill. All the objections in regard to the formation of fins, which had been made for this latter mill, will hold good here also. Since the horizontal rolls are unlike to each other, the beams will

universal mill (see Fig. 19). In this mill the rolls are of exactly similar construction and design as those of the two-high universal mill, described above. Top and bottom rolls are alike, while the center roll is different, the two former ones being of the same shape as the top rolls of the two-high mill, and the middle roll corresponding to the lower roll of the two-high mill. The vertical rolls are also equal to those of the two-high type.

It is claimed, that with this type of a mill 8 in. by 8 in. columns have been rolled successfully in the early nineties of the last century, but since that time the mill seems not to have been in use.

The Kennedy-Aiken mill of 1889 differs widely from the Seaman mill. This mill consists of three different stands, each one having a function to perform which is entirely different from that of the other two stands. The first mill (see Fig. 20) is a reversing universal roughing mill with adjustable horizontal and vertical rolls, with their axes all lying in one vert-



ical plane. The ingot is supposed to be rolled down to approximately the finished form of the beam required, by passing it forward and backward, adjusting the rolls simultaneously after each pass. It can be seen from Fig. 20, that, when the beam finally leaves the first stand, the sides and edges of the flanges are still rough. For this reason, it has to be worked upon in the second stand.

This second stand (see Fig. 21, A), is a non-reversing universal mill, the rolls not being adjustable.

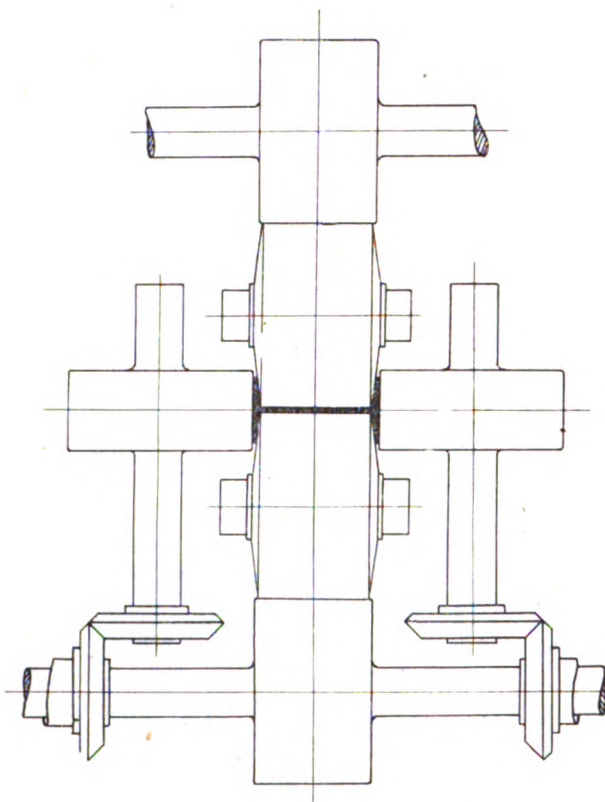


Figure 18.

The axes of all rolls lie in one vertical plane. This mill is supposed to reduce the sides of the flanges only. The beam is going through this stand once, and in order to prevent the formation of fins, slight depressions are intended to be rolled in the center of the flange.

These depressions are filled up and the edges of the flanges are reduced in the third stand (see Fig. 21, B), which is a non-reversing two-high mill, having non-adjustable horizontal rolls only. The beam is supposed to go through this stand once in order to bring it to its final shape and section.

In general, this type of a mill for rolling wide-flanged beams is, to a certain extent, a step backward, if it is compared with the Seaman mill. While with the latter only one stand is supposed to be necessary to roll down the bloom to the finished section, the former requires three stands, the second and third of which are, practically speaking, only finishing mills, the one working on the sides and the other on the edges of the flanges only. There are, however, some

advantages of this type over the other ones, described so far, which will be pointed out later in connection with review of the mills described.

The usefulness of the H-beams having been proven by practical experience, it is only natural that inventors tried to improve conditions by designing new methods of rolling or new shapes and sections of the beams. Not satisfied with the physical properties of those beams one inventor tried to overcome an apparent disadvantage by making the beams of such a shape that the moment of inertia for the X-axis is

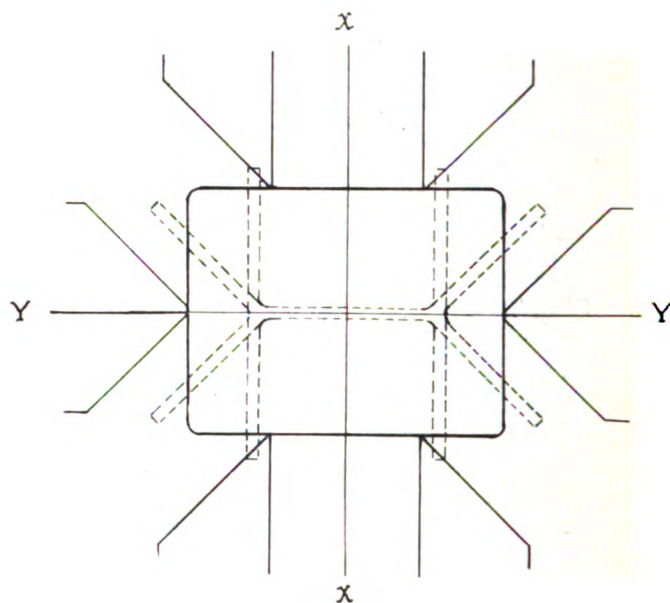


Figure 25.

equal to that of the Y-axis. Figure 22 shows a typical section of one of these beams, called after the name of the inventor the "Goebel Section." In 1910 John Goebel, Hamborn-Bruckhausen, Germany, published his design of a mill for the rolling of wide-flanged, parallel-faced beams. The new method deviates materially from the ways of rolling wide-flanged beams, applied up to that time.

The mill consists of four stands (see Figures 23 and 24), three of which, the first, the third and the fourth, are universal mills, each having four rolls with their axes all lying in one vertical plane, while the second stand is a simple two-high mill. The corresponding horizontal and vertical rolls in each stand are alike to each other and individually symmetrical.

In this type of a mill, the ingot does not go through a reversing or any other type of a roughing blooming mill, to be rolled down from the original square section to a more or less rough H-shape, but it enters the first stand (see Fig. 23, A) directly. Fig. 25 shows the ingot entering the first pass and also—in dotted lines—the beam before the flanges are straightened out and also after this is done. It can be seen that the double Y-shape is worked out of the beam directly by applying conically-shaped rolls which are forced into the rectangular ingot. In this

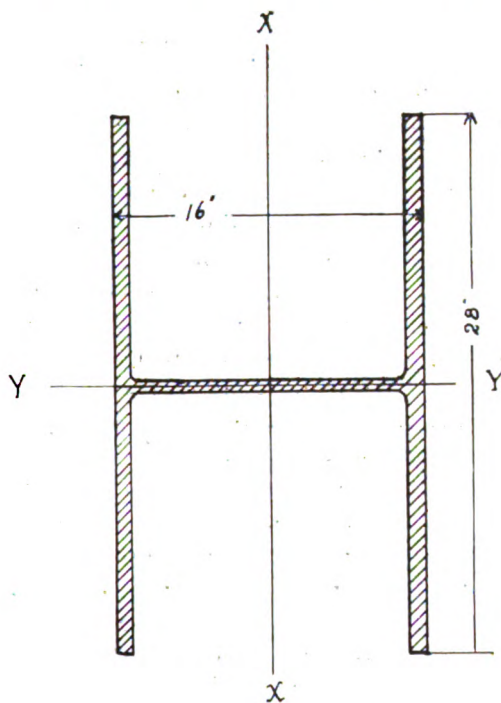


way that part of the beam which later forms the flanges is worked out diagonally, thus preventing, as is supposed, the part at the intersection between web and flanges from becoming spongy and weak and detracting from its total strength.

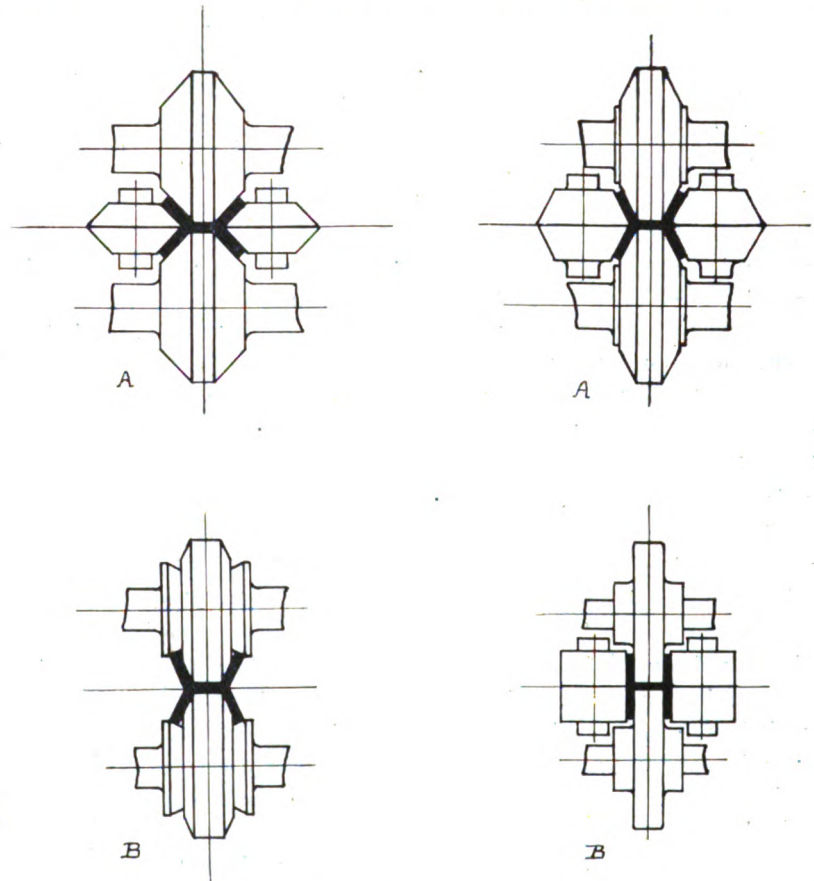
The first stand is a reversing universal roughing mill (see Fig. 23, A). Here the ingot is rolled down approximately to its final shape and size, while the flanges are worked upon under an angle of 90 deg. In the second stand, which is a two-high non-reversing mill, (see Fig. 23, B), the angle between the flanges is increased to 135 deg. Besides, the edges of the flanges are worked upon. The third stand (see Fig. 24, A) is a universal non-reversing mill for work-

A good many advantages were thought to be adherent to this mill in regard to other types. But, the objection must be made, that, instead of the two finishing stands of the Kennedy-Aiken mill, there are three stands of this kind in the Goebel mill, which are not doing very much work, while the first pass is doing practically all the work necessary to reduce the ingot from its original shape to the final section of the beam. It is of course evident that the first cost of a mill is proportional to its size—other conditions being equal—and for this reason one of the main disadvantages of the Goebel mill is the high first cost of equipment.

There is, however, another objection. Is it really



Figures 22, 23, 24.



ing on the sides of the flanges. The fourth stand, finally, a universal non-reversing mill (see Fig. 24, B) serves only for the purpose of straightening the flanges from an angle of 135 deg. to one of 180 deg. No pressure is supposed to be exerted in this stand and it is, for this reason, claimed that a careful and exact adjustment of the rolls and guides is possible which, in turn, would produce beams coming out of the rolls in a perfectly straight and smooth condition without requiring further work.

If it were intended to roll sections with exceptionally wide flanges, this might be done by changing the angle of the rolls in the first stand from 90 deg. to 60 deg., going in the second to 120 deg. instead of 135 deg. and then up to 180 deg.

necessary to roll shapes of the sizes and sections proposed or are the shapes on the market to-day sufficient to fill all wants? It is true building construction ship and bridge design demand beams or columns which have a larger section-modulus in regard to the Y-axis (see Fig. 22), than the standard sizes of beams. But this objection has been overcome by the introduction of the H-beams. For instance, the section shown in Fig. 22 weighs 181 lbs./ft. and is rolled down from an ingot 20 in. by 26 in. to the H-shape 16 in. by 28 in. The moment of inertia for both axes is equal and amounts to  $2,716 \text{ in}^4$ , while the corresponding section moduli are  $S_x = 340 \text{ in}^3$  and  $S_y = 194 \text{ in}^3$  respectively. The corresponding Bethlehem H-section, H-14, has the following properties:

Weight 227 lbs./ft., height and width 16 in. by 14.62 in.,  $S_x = 357.5 \text{ in}^3$ ,  $S_y = 127.2 \text{ in}^3$ . This shows that, while  $S_x$  is practically the same for both shapes, the figures for weight and  $S_y$  are decidedly in favor of the Goebel beam. But notwithstanding this advantage this question arises: Is the designer so badly in need

of this type of beams that he can neglect the much higher cost of manufacture of these beams? This question seemingly must be answered in the negative, because, up to the present time, no beams of the Goebel type have been rolled and the mill proper did not get beyond the model stage.

## Dry-hot vs. Cold-wet Furnace Gas Cleaning

Comparing the Efficiencies Secured and Losses Sustained Through Using Both of the Methods for Purifying Furnace Gases of Entrained Dust—Recommendations for Process.

By LINN BRADLEY, Chief Engineer; H. D. EGBERT, Engineer in Charge of Commercial Dept.; and W. W. STRONG, Physicist, Research Corporation.

Marked differences of opinion have been expressed by engineers interested in cleaning iron blast-furnace gases for use in hot-blast stoves and under boilers, in reference to the advantages of a hot-dry method over a cold-wet method. One point at issue involves the sensible heat energy in the moisture contained in the gas. Some advocates of the cold-wet methods claim that the condensation and resultant removal of the greater portion of this contained moisture by wet scrubbing, spraying or similar methods, results in a saving of some of this sensible heat energy, by reason of the fact that water vapor has a high capacity for sensible heat energy and may carry from the exit of a hot-blast stove, for example, more heat units than are sacrificed or lost when the gas is cleaned by this cold-wet method. Other advantages claimed for the latter method are: That gas burns more readily when it is free from moisture in any form; that because gas is made denser by cooling and removing the moisture it has a higher calorific value than hot gas carrying moisture; and that higher flame temperatures are obtained when the gas is cleaned by the cold-wet method.

A search through the available literature fails to disclose any extensive calculations or records of conditions obtained in practice, bearing upon these phases of gas cleaning.

This paper deals with these problems from the standpoint of the economy of using a gas of high flame temperatures, of improved stove design, and of economy in the gas-cleaning department. Calculations have been made which show that by cleaning the gases by a cold-wet method the sensible heat energy of the blast-furnace gases is greatly reduced; and, in general, this loss of heat energy is far greater than that lost from the stoves or boilers due to the sensible heat capacity of the water vapor if carried away by the exit gases. By making use of the latest values given

for the mean specific heat of gases, by Kuzell and Wigton, it will be shown that for a typical iron blast-furnace gas the sensible heat energy which is lost from the gas by the cold-wet cleaning process is in all cases much greater than the gain resulting from the removal of moisture, even if the moisture content of the furnace top gases is as great as 100 gr. per cubic foot of the gas, calculated at 32 deg. F., due consideration being given to the quantity of sensible heat energy which such an amount of moisture is capable of carrying from a hot-blast stove or boiler throughout the usual range of exit gas temperatures.

Returning to the subject of the effect of water vapor on flame temperatures, the paper shows that it would be true, as claimed by some iron blast-furnace operators, that the removal of moisture from the gases prior to combustion results in a higher flame temperature, provided no sensible heat energy were removed from the gas along with the moisture, due to cooling the gas. It is shown, however, that for typical kinds of iron blast-furnace gas, the theoretical flame temperatures are considerably higher when the cleaning method allows both the sensible heat energy and the moisture to be kept in the gas. The ideal cleaning process would be that of removing the moisture without reducing the temperature of the gases, but as no process of this kind is available it will be obvious that, other things being equal, it is better to clean these gases hot and dry and leave the moisture in the gases than to cool the gases for the purpose of cleaning and of removing water.

The gain resulting from the conservation of the sensible heat energy of the gas entering the stoves also permits of other changes in practice that appear on the whole to be advantageous. By having hot gases enter the hot-blast stoves, it is possible to obtain higher flame temperatures in the stoves. This will result in a saving of coke in preparing the furnace charge, since a hotter blast will be obtainable in the same length of time with the consumption of the same

Paper before the February meeting, American Institute of Mining Engineers.



quantity of dry top gas from the blast furnace. This hotter blast not only supplies additional heat energy, but it makes possible the attainment of higher temperatures within the furnace, and this in turn makes possible a reduction in the amount of coke charged. This effect is best understood by a reference to the excellent article by Walther Mathesius entitled "High Blast Heats in Mesaba Practice."

Furthermore, by employing higher temperatures it should be possible to store up the same quantity of heat energy in the checker work of the stoves in less

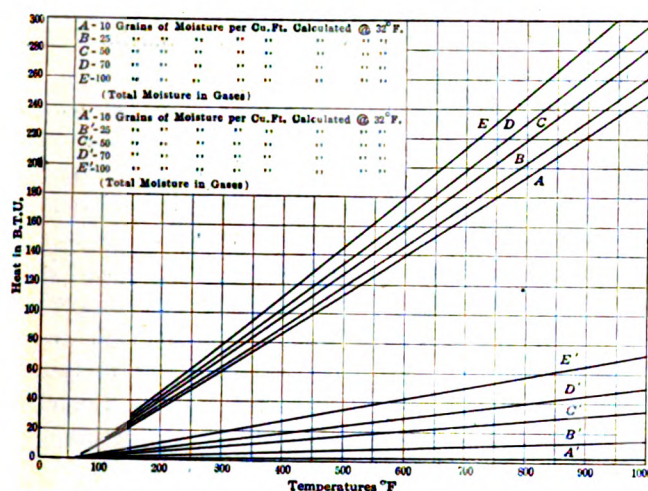


FIG. 1.—SENSIBLE HEAT CARRIED OUT BY MOISTURE IN STOVE EXIT GASES.

energy), the heat due to the temperature of the gas (sensible heat), and the latent heat of vaporization. The first type of energy may be called "the heat energy of combustion" and the second type "the sensible heat energy" of the gas. The heat energy of combustion is a function of the composition of the gases for a definite composition of the gases. The heat energy of combustion of these gases is practically constant and can be readily calculated. The sensible heat energy of a gas depends upon the quantity of gas, the volume and temperature of the gas and the mean specific heat of the gas.

The specific heat of a gas in turn depends upon the temperature of the gas and its chemical composition.

In the present discussion 1 lb. of a typical dry, clean top blast-furnace gas is taken as the unit, and is assumed to have the following percentage composition by weight:

|                 |       |
|-----------------|-------|
| CO <sub>2</sub> | 21.00 |
| CO              | 24.00 |
| H <sub>2</sub>  | 0.25  |
| CH <sub>4</sub> | 0.25  |
| N <sub>2</sub>  | 54.50 |

The presence of moisture, of dust and of excess air is measured in terms of the quantity of this foreign material per pound of such dry, clean top gas. The sensible heat energy of moist, top gas is, therefore, according to our method of calculation, the sensible

time than is now required. By carefully cleaning the gases hot-dry and by thoroughly mixing the air for combustion with the blast-furnace gases a minimum amount of excess air is required. To further increase the flame temperature, it may be feasible in some cases to utilize the heat in the stove exit gases for pre-heating the combustion air. It is obvious that the hotter the gas and the preheated air for combustion, the higher will be the flame temperature; and the same will also be true, the smaller the amount of excess air. The effect of water vapor, temperature of the gas, temperature of the combustion air, and the amount of excess air upon flame temperature is graphically shown by curves.

The curves have been plotted from a set of tables prepared from calculations based on the data on specific heats given by Kuzell and Wigton in the paper previously referred to. These tables can be applied to a large number of problems such as those in connection with hot gases coming from Portland cement kilns, smelter furnaces, cupolas, etc., where data on the sensible heat energy in the gases are required. It is possible that these tables may be submitted to the Institute for publication in another paper.

There appears to be so much room for improvement in the design and structure of hot-blast stoves that the subject has been discussed in a separate paper.

The total heat energy in a gas includes the heat which may be developed by combustion (chemical

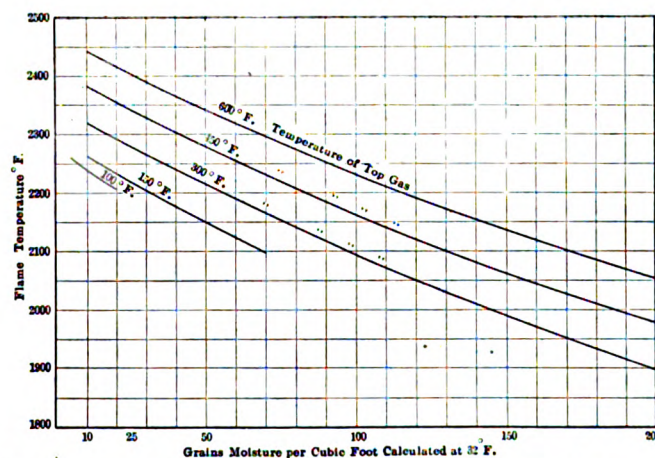


FIG. 2.—EFFECT OF MOISTURE IN FURNACE TOP GASES ON FLAME TEMPERATURE.

heat energy of 1 lb. of dry top gas plus the heat energy of the moisture which accompanies and is in addition to 1 lb. of the gases which constitute the dry top gas; i.e., the heat energies are added together.

In practice, the amount of moisture or dust in a gas is frequently measured in grains per foot of gas. This method of measuring the moisture or dust content of gas usually assumes that the moisture or dust is computed at a certain temperature of the gas such as 32 deg. F. Thus take 1 lb. of dry top gas with 20 gr. of dust per cubic foot of gas calculated at 32 deg. F., and 50 gr. of moisture per cubic foot of gas calculated at 32 deg. F. This unit of gas would contain



0.0349 lb. of dust and 0.0874 lb. of moisture. The unit of gas considered would consist of a total of 1.1224 lb. of matter, and a calculation of the sensible heat energy of 1 lb. of dry, clean, top gas with the above moisture and dust content would involve the calculation of the sensible heat energy of 1.1224 lb. of matter. The present paper, however, compares two methods of cleaning, the dry-hot and the cold-wet methods. Since both methods presuppose the removal of dust, it is not necessary to consider the sensible heat energy of the dust. In the above example the sensible heat energy would be calculated for 1.0874 lb. of matter, the dust being excluded.

In the above example the amount of dust and moisture per actual cubic foot of gas decreases with rise in temperature, for the reason that the gas expands. At atmospheric pressure 1 cu. ft. of gas at 32 deg. F. will become 2 cu. ft. at 523 deg. F. and in the example of moist, dusty gas given above, the dust content of 20 gr per cubic foot calculated at 32 deg. F., will fall to 10 gr. per actual cubic foot of gas at 523 deg. F., while the moisture content will fall from 50 gr. per cubic foot, calculated at 32 deg. F., to 25 gr. per actual cubic foot at 523 deg. F., though the percentage of dust and moisture per pound of dry, clean, top gas has remained the same. The measurement of the density of dust and moisture in a gas is, therefore, made by calculating how many grains of each 1 cu. ft. of gas would contain if reduced in temperature to 32 deg. F., the pressure being standard at 760 mm. of mercury.

For purposes of combustion it is necessary to add a certain minimum weight of air per pound of the clean, dry top gas. After combustion the chemical composition and the specific heats of the gases have been completely changed. The datum point will be taken as 60 deg. F., and the sensible heat energy of the exit stove gases will be the amount of heat energy that the products of combustion of 1 lb. of dry top gas plus the specified excess air would emit when cooled from the specified temperature of the exit gases down to 60 deg. F. In these calculations it will be assumed that the moisture content of the stove exit gases is not great enough at any time to result in condensation of any of the water vapor at the temperature at which the mixed gases actually leave the stoves. In practice, the moisture content would seldom if ever reach such an amount.

The latent heat of the water vapor need not be considered because it is lost in any cleaning method which can be adopted. In the cold-wet method the latent heat of the water vapor is absorbed by the water used during the washing process and is thus carried away by it; in the dry-hot method the latent heat of the water vapor is carried out with the stove exit gases and thereby lost.

Further, in using 60 deg. F. as the datum point for

calculations of the sensible heat energy of the exit stove gases or of the blast-furnace top gas after coming from the cleaner, it will be assumed that the gas contains 5 gr. of moisture per cubic foot of gas calculated at 32 deg. F. This means that the sensible heat energy is referred to that of the same gas practically saturated with moisture at 60 deg. F. Such a datum point is convenient because any kind of a gas cleaned by the cold-wet method usually comes out at about 60 deg. F., and is practically saturated with moisture. As our comparison is made between a dry-hot and a cold-wet method of cleaning it is natural to assume conditions prevalent in the cold-wet method as the datum point.

Consider 1 lb. of dry, clean, top gas 700 deg. F., containing 20 gr. of dust and 25 gr. of moisture, both calculated per cubic foot of gas at 32 deg. F. Our unit of dusty and moist gas weighs 1.0787 lb. It is found that the sensible heat energy in the 1 lb. of top gas and that in the moisture (which would be lost if the gas passed through a cold-wet cleaning apparatus, thus reducing its temperature to 60 deg. F.) would be 174.69 B.t.u. =  $Q_t$ . By the cold-wet method of cleaning that cools the gas to 60 deg. F., the above  $Q_t$  units of heat energy are lost for every pound of dry top gas, plus a specified moisture density.

In the dry-hot method of cleaning, no material lowering of temperature of the combustible gases for the stoves need take place. This condition is practically feasible when the electrical method of cleaning is used because the electrical precipitators need not be more than 15 or 20 ft. in length. The length of the gas mains and connections need not, therefore, be greatly increased, and, furthermore, they may be insulated so as to conserve the heat energy of the gases.

In the dry-hot method of cleaning the 25 gr. of moisture per cubic foot of gas, mentioned above, remain in the gas, and are carried into the stoves and then out with the products of combustion. The only difference between the exit gases from dry-hot cleaning and cold-wet cleaning in the present example is that in the one case there are 20 gr. of moisture per cubic foot of gas standard more than in the other case. Let us assume that the exit gases leave the hot-blast stoves at 600 deg. F., which is a fair average. With the hot-dry method of cleaning these gases will carry away 8.83 B.t.u. of sensible heat energy for every pound of dry top gas over and above what the same gases would have carried out had they been cleaned by a cold-wet method, due to the greater amount of moisture left in the gas when cleaned by the hot-dry method. Let this energy be  $Q_e$ . The saving in sensible heat energy by the hot-dry method of cleaning as compared to the cold-wet method is:

$Q_t - Q_e = 174.69 - 8.83 = 165.86$  B.t.u. per pound of dry top gas.

In the above comparison any energy changes due



to expansion or contraction of the gases can be neglected because the exit gases are under practically the same condition of pressure and temperature for both methods of cleaning.

Assuming a ton of iron to represent a production of 12,000 lb. of such typical top gas, a hot-dry method of cleaning the gases would conserve 12,000 ( $Q_t - Q_e$ ) = 1,990,320 B.t.u. per ton of iron in the above example.

#### Data and Theory of the Conservation of the Sensible Heat Energy of Gases.

In the present article the term "grains of dust per cubic foot of gas calculated at 32 deg. F., or 0 deg. C." will be spoken of as "grains of dust" or as "grains of dust per cubic foot." "Grains of moisture" will mean grains of moisture per cubic foot of gas when the temperature of the gas is calculated at 32 deg. F., and the pressure is 760 mm. of mercury. As previously stated, the moisture content is separate and in addition to the typical gas.

$C_p$  is the specific heat of a gas at constant pressure and represents the ratio of the amount of the heat energy required to raise the temperature ratio of the amount of the heat energy required to raise the temperature of a unit mass of the gas one degree compared with that required to raise the temperature of the same mass of water one degree (from the temperature of maximum density).

$C_m$  is the mean value of  $C_p$  between the temperature  $t_1$  and  $t_2$ .

The equations used for calculating the sensible heat energy of various gases are obtained from the following equations, where  $t$  is the temperature Fahrenheit. These equations were used by Kuzell and Wigton. For references as to the experimental determination of the constants in these equations the reader is referred to that part of the bibliography pertaining to specific heats.

#### Mean Specific Heats of Gases under Constant Pressure.

Mean Specific Heats of Gases under Constant Pressure  
(To 2,000 deg. C. or 3,600 deg. F.)

$C_m$ , (0 to  $t$ ) for  
1 lb. in B. t. u.

|              |                                         |  |
|--------------|-----------------------------------------|--|
| $N_2$ .....  | $0.2411 + 0.0000099t^2$                 |  |
| $O_2$ .....  | $0.2111 + 0.000007t$                    |  |
| $H_2O$ ..... | $0.4701 - 0.0000118t + 0.0000000127t^2$ |  |
| Air.....     | $0.2342 + 0.0000066t$                   |  |
| $CO$ .....   | $0.2413 + 0.0000099t$                   |  |
| $H_2$ .....  | $3.3381 + 0.000124t$                    |  |
| $CO_2$ ..... | $0.1975 + 0.0000388t - 0.0000000043t^2$ |  |
| $CH_4$ ..... | $0.5904 + 0.0000411t$                   |  |

The term "flame temperature" in this paper will refer to the temperature that a gas will attain when one assumes that the energy of combustion is added to the sensible heat energy of the gas; all the resultant heat energy being used to raise the temperature of the gas, calculated on the basis of the values of the mean specific heat as given by the above equations. The actual flame temperature will be lower because some

of this heat energy is conducted or radiated away before complete combustion takes place. The pressure of the gases is considered to be constant and standard.

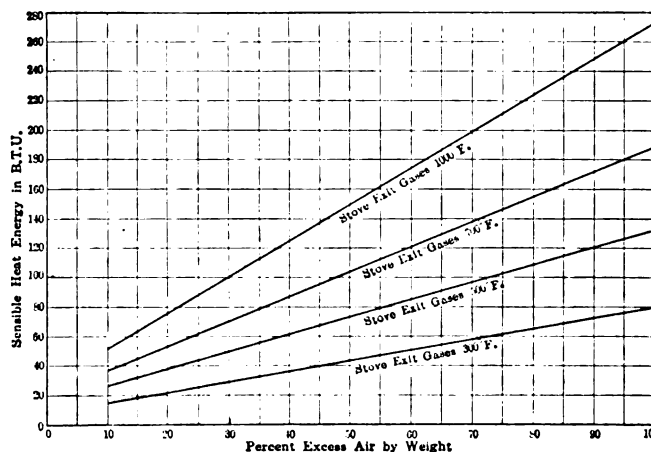


Figure 3.

Slight changes in pressure would make only very small differences in the calculations and conclusions.

#### Some Conclusions Derived from Sensible Heat Data.

The mean specific heat at constant pressure increases for all gases so far as known, as the temperature is increased. In some instances, values of the specific heats at constant pressure are assumed for

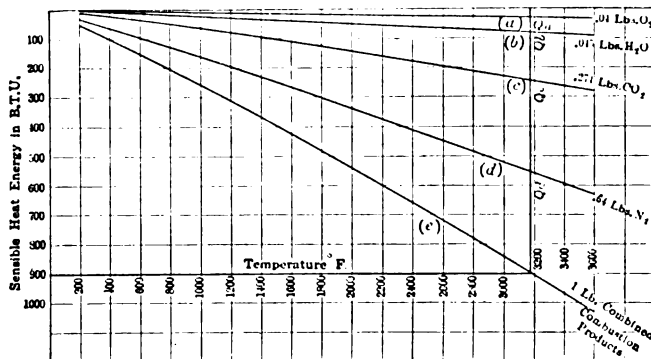


FIG. 4.—SENSIBLE HEAT ENERGY ABOVE 0° F. IN THE DIFFERENT PRODUCTS OF COMBUSTION FROM BURNING 1 LB. OF TYPICAL TOP GAS.

temperatures as high as 3,600 deg. F. Undoubtedly, the measurements of specific heats at these temperatures are not yet very exact, but it is probable that the results are of the right order of magnitude and therefore do not invalidate any conclusions drawn from them which are essentially qualitative. The conclusions are also applicable to gases of quite a range of composition, the results being worked out in a similar manner to that used here in the typical example.

In general, the sensible heat energy lost in cooling iron blast-furnace gas by a cold-wet method of cleaning is much greater than that carried out with products of combustion by the moisture left in the gases in a hot-dry method of cleaning. Consider the curves in Fig. 1. In E and E' the typical blast-furnace top



gas has a moisture content of 100 gr. From curve E it will be seen that if the top gas enters the wet cleaner at 300 deg. F., it will lose 78 B.t.u. per pound typical top gas when cooled to 60 deg. F. From curve E' it will be seen that if the same gas is burned without reduction of moisture content and the product of combustion leaves the stove at 1,000 deg. F., the accompanying moisture will carry away 74 B.t.u. per pound of typical top gas. Even under these very exceptional conditions, a hot-dry method of cleaning would result in a saving of 4 B.t.u. per pound of typical top gas.

Consider the other extreme condition. Assume the blast-furnace gas to enter a hot-blast stove at 900 deg. F. From curve E it will be seen that on cold-wet cleaning 284 B.t.u. would be lost per pound of typical top gas. Also assume that the gas leaves the stove at 1,000 deg. F. Then from curve E' it will be seen

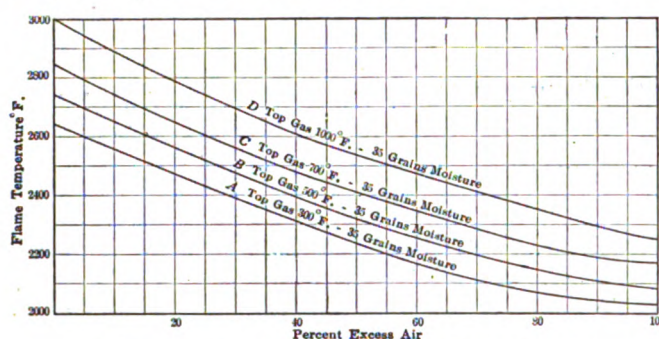


FIG. 5.—EFFECT OF EXCESS AIR ON FLAME TEMPERATURES

that the moisture accompanying 1 lb. of typical top gas will carry away from the stove 74 B.t.u. In this case there will be a saving of 210 B.t.u. per pound of typical top gas. The other curves show results more favorable to the hot-dry method of cleaning, since the moisture contents are less. In practice the average moisture content seldom exceeds 35 gr. per standard cubic foot of typical top gas, even when the stock in the furnace has been watered to reduce dust losses.

The effect of moisture on flame temperatures is given in the curves in Fig. 2. The effect of increasing the moisture content from 10 gr. to 100 gr. would be to lower the flame temperature produced by burning the typical gas from 2,320 deg. F., to 2,090 deg. F., for the gas entering the burner at 300 deg. F., and from 2,460 deg. F. to 2,230 deg. F., for the gas entering the burner at 600 deg. F. Now suppose that these gases had been cooled to 60 deg. F. and the moisture thus reduced to 5 gr. The flame temperature would then have been about 2,250 deg. F. In other words, a cold-wet method of cleaning would have resulted in slightly higher flame temperatures in the above cases provided the moisture content was 100 gr. or greater. For a 50-gr. moisture content the cold-wet method would give a higher flame temperature if the top gases were originally at 300 deg. F., whereas if they were at 450 deg. F., or 600 deg. F., or over, the hot-dry method of clean-

ing would give the higher flame temperature. From the point of view of flame temperatures, there are certain temperature and moisture-content limits, on one side of which a hot-dry method of cleaning gives the higher flame temperature, while on the other side the cold-wet method of cleaning gives the higher flame temperatures. Operating conditions quite usually lie in the hot-dry region, as can be seen by a study of the curves.

The effect of excess air in increasing the amount of sensible heat energy carried out from the stoves and boilers by the exit gases at different temperatures is given in the curves of Fig. 3. These curves assume a moisture content for the top gas of 35 gr. (which is probably a fair average). The relative loss of heat energy due to excess air increases as the temperature of the exit gases is increased. The curves show how very important it is to keep the excess air down to a minimum. Thorough mixing of air and gas, and having the mixed gases hot on entering the stoves and boilers, are important essentials, and some automatic device for regulating the air input for variations (due to furnace changes) in the quantity and composition of the blast-furnace top gases should be used.

The sensible heat energy in the constituents of the stove exit gases resulting from the burning of 1 lb. of dry top gas, carrying 35 gr. of moisture with 60 per cent excess air, the air carrying 5 gr. of moisture, is given in the curves of Fig. 4 for various temperatures of the exit gases.

Although not plotted in that way, these curves could be made to show the sensible heat energy carried from the stoves and boilers by the moisture present in the original top gas and by the excess air. Such curves would give at various temperatures the loss of heat energy due to moisture and to excess air.

The curves of Fig. 5 show the effect of excess air on flame temperatures. A range of excess air from 20 to 60 per cent lowers the flame temperature more than 300 deg. F. As the amount of excess air is increased, the flame temperature depends less and less upon the temperature of the blast-furnace top gas. The great importance of reducing the amount of excess air, both as regards the conservation of sensible heat energy and the maintenance of a high flame temperature, is shown very positively by these curves.

To sum up, the statement frequently made, that the cold-wet method of cleaning gases is advisable because moisture is removed from the top gases, thereby permitting higher flame temperatures and obtaining a decrease in the lost of sensible heat energy, is not true under the conditions of operation assumed in the paper. It is shown herein that these conditions are fairly typical and representative. Unless the gas has a moisture content exceeding 100 gr. per cubic foot, or its temperature is extremely low, sensible heat energy is conserved by using a hot-dry method of cleaning.



The conservation of this sensible heat energy by a hot-dry method of cleaning also permits of a higher flame temperature, if the moisture content is not too high. The hot-dry method also makes it possible to operate with a minimum amount of excess air for combustion, this in turn promoting higher flame temperatures and conservation of gas.

In some ores a considerable amount of compounds of potash, zinc, lead, arsenic, antimony, etc., may accompany the compounds of iron, copper, etc., for which the ore is being smelted. Under present conditions this more volatile part of the ore may be carried away in the top gas. A dry method of cleaning may allow the recovery of certain of these volatile compounds, thus making commercially possible the treatment of a greater variety of ores. At the present time the application of the electrical method of cleaning blast-furnace gas from iron ore containing zinc is being developed and other problems similar to this are also under consideration.

Under practical operation conditions, many other conditions relating to the cleaning process must be considered. A few of these may be briefly considered. The cold-wet process of cleaning is usually more or less automatic in operation and requires comparatively little attention. Rather large quantities of water are used and considerable power is consumed in handling this water, and in forcing the gases through the system. The washers are comparatively large and the initial expense of installation is large. In some instances, a problem arises as to the disposal of the muddy water, it often being illegal to allow this contaminated water to run into the streams, while in other instances water is not abundant and its use for gas cleaning may be prohibitive.

There is a hot-dry method of cleaning that promises to be very advantageous for the purpose of cleaning these gases. The electrical precipitation processes make use of a high-tension electrical discharge which sweeps out the suspended matter from the surrounding gas. The electrical method does not cool the gas, it precipitates the suspended dust in a dry state, thus making it easy to reclaim this material. The operation is practically automatic and the energy consumption is small.

The cleaning power of the electrical method is practically complete, in many instances being as high as 99 to 100 per cent.

The degree of cleaning is greater than that usually obtained by wet methods in general and is ample for stoves and boilers. Indeed the results of recent tests have indicated the probability that even with a single pass precipitator the gases would be cleaned to the degree required by internal-combustion engines.

In general the sensible heat energy of the top gas from iron blast furnaces above 60 deg. F. is much greater than the sensible heat energy of the moisture

carried away from the stoves. A hot-dry method of cleaning the gases that conserves the sensible heat energy of the top gases is therefore more efficient as an energy saver than a wet method of cleaning that reduces the moisture content to 5 gr. (per cubic foot calculated at 32 deg. F.), thus decreasing the sensible heat energy carried out by the moisture leaving the

By conserving the sensible heat energy of the top gas a dry-hot method of cleaning the gas (having a moisture content of not more than about 0 gr. of moisture) generally permits of a higher flame temperature than would be obtained by a wet process of cleaning that reduces the moisture content to 5 gr. excess air being considered constant.

Excess air lowers the flame temperatures. Curves are given that show this effect for various amounts of excess air.

A dry-hot method of cleaning permits of the immediate recovery of the precipitated fume, dust or smoke in a readily usable condition.

Curves are given showing the flame temperatures with the typical top gases entering the furnace at 300 deg., 450 deg. and 600 deg. F., the gases containing variable quantities of moisture ranging from 10 to 200 gr. per cubic foot. Taking the top gas with a moisture content of 100 gr. and entering the stove at 600 deg. F., the curve shows a lowering of the flame temperature of 220 deg. F., from about 2,480 deg. F. The wet method of cleaning would have cooled the entering gases from 600 deg. F., to 60 deg. F., thereby resulting in even a lower flame temperature.

Assuming a furnace to give 6,000,000 lb. of gas per 24 hr., the saving by the dry-hot method of cleaning of 140 B.t.u. per pound of gas (a representative case in practice) compared with the wet method would result in a saving of \$69.67 per day, assuming coal to cost \$2.50 net per ton and to contain 15,000 B.t.u. per pound. This equals about \$25,000 per year.

The electrical method is unique in that it is the only known method that operates very efficiently for removing small suspended particles. For this reason the electrical method should be especially well adapted for Mesaba and similar ores, where the dust in the top gas is very fine.

The electrical method of cleaning the top gas should prevent the troubles of slow ignition and imperfect combustion often encountered when wet cleaning is used. These ignition troubles are due primarily to the loss of sensible heat energy.

The use of clean gas permits of a much more efficient type of stove construction since it eliminates cleaning. For a similar reason, boilers will operate more satisfactorily.

The dry method of cleaning furnace gases permits of the collection of such volatile constituents of the ore as potash, zinc, lead, tin, mercury, arsenic and antimony compounds.

# Potash as One Blast Furnace By-product

Continuing the Outlining of the Possibilities for Recovering Potash and Its Compounds from the Flue Dust Deposited by the Blast Furnace and Its Auxiliaries.

By R. J. WYSOR.

Table 1 shows analyses representing 3 months' shipments in 1916, including hundreds of thousands of car loads of each variety, of the chief materials charged into our blast furnaces. Besides the alkali metals, percentage of silica and alumina are given, also iron contents of the iron ores, all analyses being expressed on the "natural" basis.

**TABLE I—Analyses of Materials of Blast-furnace Charge.**

| Materials                | Kind | Source       | Fe    | SiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | K <sub>2</sub> O | Na <sub>2</sub> O |
|--------------------------|------|--------------|-------|------------------|--------------------------------|------------------|-------------------|
| <b>Iron Ores:</b>        |      |              |       |                  |                                |                  |                   |
| Tofo .....               | Mag. | Chile        | 65.0  | 2.7              | 0.9                            | 0.25             | 0.48              |
| Juragua .....            | Mag. | S. C'st Cuba | 54.5  | 13.0             | 2.7                            | 0.29             | 0.77              |
| Mayari .....             | Lim. | N. C'st Cuba | 38.0  | 2.0              | 10.0                           | 0.06             | 0.25              |
| Swedish .....            | Mag. | Nor. Sweden  | 66.0  | 2.8              | 1.1                            | 0.27             | 0.82              |
| Port Henry Conc. Mag.    |      | Nor. N. Y.   | 63.5  | 4.4              | 1.8                            | 0.28             | 0.68              |
| Harmony Cobbed. Mag.     |      | Nor. N. Y.   | 63.0  | 10.0             | 3.4                            | 0.25             | 0.55              |
| Barton Hill .....        | Mag. | Nor. N. Y.   | 64.0  | 8.3              | 1.9                            | 0.22             | 0.77              |
| Cheever .....            | Mag. | Nor. N. Y.   | 59.5  | 11.4             | 1.0                            | 0.21             | 0.92              |
| Sterling .....           | Mag. | So. N. Y.    | 55.0  | 8.6              | 2.0                            | 0.33             | 0.95              |
| Manganate .....          | Hem. | Lake Men'ee  | 45.5  | 7.2              | 3.3                            | 0.24             | 0.47              |
| Norman .....             | Hem. | L'ke Gogebic | 55.5  | 5.4              | 1.5                            | 0.29             | 0.32              |
| Eureka .....             | Hem. | L'ke Gogebic | 54.5  | 7.1              | 1.5                            | 0.26             | 0.35              |
| Mary .....               | Hem. | Lake Marq.   | 50.5  | 7.8              | 2.5                            | 0.28             | 0.55              |
| <b>Manganese Ores:</b>   |      |              |       |                  |                                |                  |                   |
| Brazilian .....          |      | Brazil       | ..... | 7.5              | 3.0                            | 0.88             | 0.21              |
| Cuban .....              |      | S. C'st Cuba | ..... | .....            | .....                          | 1.12             | 0.77              |
| Oriental .....           |      | India        | ..... | .....            | .....                          | 1.68             | 0.19              |
| <b>Fuel:</b>             |      |              |       |                  |                                |                  |                   |
| Lehigh by-prd. cke. .... |      | W. Va. Coals | ..... | 5.1              | 3.4                            | 0.28             | 0.30              |
| <b>Flux:</b>             |      |              |       |                  |                                |                  |                   |
| McAfee limestone .....   |      | Nor. N. J.   | ..... | 2.5              | 0.9                            | 0.36             | 0.70              |
| Average dolomite .....   |      | Beth'm Vic.  | ..... | 3.5              | 1.5                            | 0.82             | 0.97              |

Two or three of the above ores are mixtures of magnetite and hematite, with the former predominating.

In the course of this investigation, samples of slag and flue dust from all of our Bethlehem furnaces were collected continuously over a period of 4 weeks during June and July, 1916, and analyzed for the alkalis. The analyses in Table 1 of ores, fuel and flux, are fairly representative of the materials charged during this period. The same coke and stone (half limestone and half dolomite) are used in all furnaces. The percentages of potash and soda in the ore mixture charged in each furnace during the above period are as follows:

| Furnace                                         | A    | C    | D    | E    | F    | G    |
|-------------------------------------------------|------|------|------|------|------|------|
| K <sub>2</sub> O in ore mixture, per cent ..... | 0.28 | 0.27 | 0.28 | 0.29 | 0.28 | 0.28 |
| Na <sub>2</sub> O in ore mixture, per cent..... | 0.63 | 0.43 | 0.65 | 0.50 | 0.51 | 0.63 |

From the foregoing data, and from known weights of materials charged, Table 2 has been constructed, showing the weights of potash and soda charged per ton of pig iron produced.

The ratio of potash to soda is considerably higher in the coke than in the ore and stone. From Table 2 it will be seen that for each ton of pig iron produced, nearly 60 pound of the alkali oxides are charged, constituents which certainly are of considerable impor-

tance in the working of the furnace, yet of which relatively little cognizance has been taken in the past.

However, due largely to the relatively high percentage of alkalis in our fuel and flux, and on account

**TABLE II**

Potash (K<sub>2</sub>O)

Soda (Na<sub>2</sub>O)

|                                                               | Gross Ton | Pounds | Per Cent of Total Contributed | Gross Ton | Pounds | Per Cent of Total Contributed |
|---------------------------------------------------------------|-----------|--------|-------------------------------|-----------|--------|-------------------------------|
| Average weight in ore mixture, all furnaces, per ton pig..... | 0.0046    | 10.3   | 46                            | 0.0062    | 20.6   | 58                            |
| Average weight in coke all furnaces, per ton pig .....        | 0.0026    | 5.8    | 26                            | 0.0028    | 6.3    | 18                            |
| Average weight in stone all furnaces, per ton pig .....       | 0.0028    | 6.3    | 28                            | 0.0039    | 8.7    | 24                            |
| Total .....                                                   | 0.0100    | 22.4   | 100                           | 0.0159    | 35.6   | 100                           |
| Ratio potash to soda charged                                  | 1:1.6     |        |                               |           |        |                               |

of the considerable quantity of alkali bearing flue dust removed, it is my opinion that more potash and soda are charged into our blast furnaces, per unit of iron produced, than in any other large plant in this country

## Action of Alkalies Within the Furnace.

It is probable that a considerable part of the potash and soda charged into a blast furnace is evolved from the top by direct volatilization or heat decomposition, though alteration by chemical reaction of the alkaline salts or compounds liberated may occur before they have left the furnace. It is certain that a large part of the alkalis is carried down into the hotter zones of the furnace and converted into cyanides by reaction with red-hot carbon. Some investigators have attributed an appreciable part of their ore reduction to the action of cyanides, inferring that after being oxidized and driven to the cooler upper portion of the furnace, they condense and are again carried down into the reducing zone. Whatever the action, it is self-evident that eventually the same amount of alkalis must be carried out of a furnace that is charged, and this takes place through the following avenues of escape:

In Chemical Combination in the Slag.—The literature is almost barren with reference to the presence of alkalis in blast-furnace slag. On account of the readiness with which the compounds of these metals are



sublimed and carried out of the furnace with the gas, it might be inferred that only a negligible proportion would be found in the slag. This is far from the truth.

| Furnace                                     | Period Included, 1916 | % Alkalies in Slag |                   | % Silicon in Pig Iron |
|---------------------------------------------|-----------------------|--------------------|-------------------|-----------------------|
|                                             |                       | K <sub>2</sub> O   | Na <sub>2</sub> O |                       |
| A                                           | 6/25 to 7/8           | 0.48               | 0.96              | 1.07                  |
| A                                           | 7/9 to 7/22           | 0.38               | 0.70              | 1.06                  |
| C                                           | 6/25 to 7/8           | 0.17               | 0.22              | 1.62                  |
| C                                           | 7/9 to 7/22           | 0.18               | 0.22              | 1.70                  |
| D                                           | 6/25 to 7/8           | 0.42               | 0.36              | 1.22                  |
| D                                           | 7/9 to 7/22           | 0.40               | 0.40              | 1.20                  |
| E                                           | 6/25 to 7/8           | 0.56               | 0.60              | 1.50                  |
| E                                           | 7/9 to 7/22           | 0.65               | 0.66              | 1.35                  |
| F                                           | 6/25 to 7/8           | 0.29               | 0.36              | 1.27                  |
| F                                           | 7/9 to 7/22           | 0.40               | 0.64              | 1.27                  |
| G                                           | 6/25 to 7/8           | 0.34               | 0.68              | 1.27                  |
| G                                           | 7/9 to 7/22           | 0.35               | 0.72              | 1.06                  |
| Average for all furnaces, first period..... |                       | 0.38               | 0.53              | 1.32                  |
| Average for all furnaces, second period..   |                       | 0.39               | 0.56              | 1.29                  |
| Average ratio potash to soda in slag.....   |                       |                    |                   | 1:1.4                 |

Average samples from each of six furnaces in operation for two bi-weekly periods were carefully analyzed for potash and soda, with the results shown in Table 3. The slags were all normal for our practice, averaging about 35 per cent silica, 13 per cent alumina, 13 per cent magnesia and the remainder lime, etc. In order to give an idea as to the hearth temperatures, the average silicon contents of the pig iron produced over the same periods are also tabulated.

The calculated weight of slag produced during this period was about 0.52 ton per ton of pig iron produced, which would account for a loss of alkalies as follows:

|                                          | Pounds | % of Total Charged |
|------------------------------------------|--------|--------------------|
| Average potash in slag per ton pig ..... | 4.5    | 20                 |
| Average soda in slag per ton pig .....   | 6.3    | 17                 |

The percentage loss of the two alkalies in the slag is seen to be about the same, being somewhat greater in the case of potash.

In the case of "C" furnace, almost the same weight of alkalies was charged and the same weight of slag was produced per ton of iron, as at the other furnaces, yet it will be noted that the percentages of alkalies in the slag is much lower. This probably may be attributed to the higher hearth temperatures, as indicated by the higher silicon iron produced. However, I am unable to generalize this theory because further data are lacking at present.

On old blast-furnace slag dumps, deposits of a yellowish or almost white substance frequently may be found in sheltered crevices or small grottoes, into which water has percolated through overlying masses of slag, thus becoming more or less charged with soluble salts. The substance left by evaporation may be in the form of stalactites, thin circular crystals, or of a dry powder. Considerable quantities of this material may be seen at Bethlehem where portions of our slag dump are being removed for concreting and other work. Two representative samples, one of light-yellow material, and the other nearly pure white, were obtained and, after being dried, were found to have the following proximate composition:

| Sample | SiO <sub>2</sub> | Fe <sub>2</sub> O <sub>3</sub> +Al <sub>2</sub> O <sub>3</sub> | MnO   | CaO   | MgO  | K <sub>2</sub> O | Na <sub>2</sub> O | Total Sulphur | Sulphide Sulphur | Cl    |
|--------|------------------|----------------------------------------------------------------|-------|-------|------|------------------|-------------------|---------------|------------------|-------|
| White  | 0.20             | 0.36                                                           | 0.04  | 26.47 | None | 8.66             | 4.27              | 38.3          | 14.5             | trace |
| Yellow | 0.38             | 0.13                                                           | trace | 17.00 | None | 17.64            | 8.76              | 37.6          | 25.6             | trace |

The above analyses are interesting and instructive. We note the presence of nearly twice as much potash as soda in these samples, whereas in the raw slag the figures are almost reversed. The simultaneous presence of large amounts of potash, soda and sulphur indicate that, to a limited extent, the alkalies are efficient desulphurizers in the blast furnace.

Although not directly connected with the subject of this paper, I wish to call attention in passing to the apparent significance of the relatively large percentage of lime and sulphur, and the absence of magnesia in the above leachings. We know that practically without exception magnesium salts are more soluble in water than the corresponding salts of calcium. Our flux at Bethlehem for years has consisted of half limestone and half dolomite; as previously stated, the magnesia content of the slags averages about 13 per cent. The above facts furnish new evidence, so far as can be ascertained, as the superiority of lime over magnesia as a desulphurizing agent in the blast furnace. Further corroborative tests were made by subjecting fresh, powdered samples of slag to 24-hr. leaching tests in hot and cold water. In every case, appreciable amounts of sulphur (in both sulphide and sulphate state) and lime, were found in about equivalent ratio for combination, and never more than a trace of magnesia.

As Cyanide or Other Volatile or Inflammable Compound through the Iron and Cinder Notches.—Part of the fume arising from the molten iron, and especially from the slag running from the furnace, is undoubtedly alkali compounds. I have often noticed a peculiar lavender or violet flame around the iron and cinder notches during casting or flushing, which I believe is due to some alkali salt or salts burning. The fume arising from the iron and cinder runners certainly contains a considerable percentage of alkalies.

By Liquid Exudation or Deposition from Gas Around the Tuyeres, Coolers, Mantel and Cooling Plates.—Occasionally while removing a tuyere or cooler, a stream of liquid "cyanide," resembling water, will run out of the furnace, or can be seen exuding from the lining.

When cooling plates above the mantel burn out, due to the failure of the water supply, and a little gassing has commenced, beautiful white and yellow or yellowish-red crystals often build up around the apertures. In mass, all of these crystals appear to be strongly deliquescent, and hence it is difficult to obtain photographs showing clearly defined crystal faces.

When examined on the hot furnace shell with a good hand glass, there is seen sometimes a mixture of different kinds of crystals and in different systems. Several samples of brilliant yellow crystals were secured and a few reddish-yellow which are very likely potassium ferrocyanide. Usually, however, the crystals are pure white, and have been found to be chiefly ammonium chloride. An analysis was made of some of these white crystals, slightly contaminated, taken from two different furnaces at different times, the results being;  $\text{SiO}_2$ , 0.78 per cent;  $\text{Fe}_2\text{O}_3$  +  $\text{Al}_2\text{O}_3$ , 2.49;  $\text{CaO}$ , 0.29;  $\text{MgO}$ , 0.28;  $\text{K}_2\text{O}$ , 0.24;  $\text{Na}_2\text{O}$ , 0.12;  $\text{Cl}$ , 62.39;  $\text{CO}_2$ , 0.72;  $\text{CN}$ , none;  $\text{NH}_3$ , 30.69 per cent.

Liquid material sometimes also exudes from around the mantel plates and solidifies in heavy columns or stalactitic masses on the shell. This substance containing some cyanides, is highly deliquescent. Upon several occasions, samples which have been brought into the office in the evening have disappeared into puddles of liquid during the night. A fairly complete analysis of this material showed the following complex composition:  $\text{SiO}_2$ , 1.11 per cent;  $\text{Fe}_2\text{O}_3$  +  $\text{Al}_2\text{O}_3$ , 3.17;  $\text{CaO}$ , trace;  $\text{MgO}$ , 0.22;  $\text{K}_2\text{O}$ , 46.15;  $\text{Cl}$ , 16.94;  $\text{Na}_2\text{O}$ , 18.08;  $\text{CO}_2$ , 9.64;  $\text{CN}$ , 7.84;  $\text{NH}_3$ , none;  $\text{Fe}(\text{CN})_2$ , 5.25;  $\text{CNS}$ , 0.17.

The dissimilarity between the composition of this material and the crystals is striking. The excess of potash over soda is noteworthy, as is also the presence of considerable percentages of chlorine in both stalactites and crystals. As will be seen from later analyses of flue dust, an appreciable amount of chlorine, doubtless practically all charged, is carried out of the top of the furnace. Although no special investigation has been made, we know some of it originates in the coke, which is quenched with water rich in chlorides; also, it is doubtless carried by some of the ores as chlorapatite or other chlorine-bearing mineral.

Whereas certain other investigators have shown considerable percentages of cyanide compounds in dust samples collected through the shell of the blast furnace, or from the flue dust, only the last-mentioned sample, of all collected in this investigation, has shown more than a trace of cyanide. While probably present in considerable quantities in the hearth and bosh, the alkali cyanides forced into the upper zones are evidently almost entirely decomposed before leaving the furnace.

In the case of one furnace which has recently completed a long campaign, most of the cooling plates above the mantel burned out because of failure of water at one time or another. After the wall had worn thin, it was necessary to use a spray cooling pipe on the outside of the shell. To prevent water from entering the furnace, the feed-water pipes were cut off and the holes through the shell covered with "scab" plates on top of asbestos pads. After several months, when these plates were removed, it was found that some of

these asbestos pads were dyed deep yellow, and several showed greenish and bluish tinges, indicating complex cyanides. When an old furnace is laboring under high pressure, and is seen to be gassing freely about the mantel, a strong acrid odor, doubtless ammonium chloride, is sometimes evident.

By Combination with the Brickwork or as an Accretion in the Form of Cyanide, Etc., and Removal when the Furnace is Blown Out.—This is, of course, a relatively small but very interesting part of the alkalies charged during a campaign. Several authors have suggested that reconstruction of brickwork in certain stacks, particularly in the middle and upper zones, was due to action of alkalies. However, so far as chemical action is concerned, rather more importance has been attributed to reaction between carbon monoxide and iron oxide spots in the brickwork, with subsequent disruption of the brick mass. The destruction of linings is doubtless hastened somewhat in furnaces in which the burdens are relatively rich in alkalies.

The average sample of the hearth brick used in one furnace lining at Bethlehem by careful analysis showed a total alkali content of 1.60 per cent. After blowing out, a sample was secured of a number of these brick near the bottom of the hearth, appreciably discolored when broken, which showed a total alkali content of 3.36 per cent. Higher up in the lining the alkali enrichment is greater. Samples of pure white, mixed cyanides, etc., have been recovered in various plants from protected crevices in the brickwork, around the boshes after furnace campaigns, and a great deal more would be found if the contents of the stack could be removed dry.

The presence of ammonia around furnaces directly after being blown out is of course, well known. Sometimes enormous quantities are evolved, the odor being apparent until the entire lining is removed and the hearth cleaned out. The chief source of ammonia gas is undoubtedly the alkali cyanides and ammonium chloride which decompose in the hot water or water vapor introduced to cool down the furnace. In passing, it is interesting to recall that a very small part of the cyanide produced in a furnace is fixed and carried into the salamander in the form of the peculiar compound, titanium cyano-nitride. The excess accumulation of alkalies in the brickwork, or in salt deposits in a furnace lining after a campaign, may literally amount to several tons.

By Evolution in the Gas.—The heavy flue dust which is carried out of the top of the furnace by the gas current, of course, contains approximately its normal percentage of alkalies. The finer portions of ore, stone and coke dust doubtless average somewhat higher in alkali content than the entire materials as charged

(Concluded Next Month.)



# *Types of Different Blast Furnace Slags*

Effect of Change of Burden; Influence of Cold Air; Relation  
That Hearth Temperature Bears to Different Slag Types;  
Development of Slag Series.

By WALLACE G. IMHOFF.

At first glance there seems to be no regularity to blast furnace slags. Any furnaceman will tell you there are no two slags exactly alike, there are no two casts of iron the same, there is always something that makes one run different from another. There are just grounds for thinking the above for there are so many types of slags, so many types of iron, sometimes produced under one condition, sometimes under another, that no systematic laws seem to govern them at all. The writer is very sorry not to be able to reproduce the various slag types in colors, but the reason was not because he did not try. After failing to reproduce these slags as they were the sketches given were the next best attempted.

There is a regularity to slags. The basis for their formation, appearance and peculiarities is determined by some of the following elements—heat or cold, hearth temperatures, relative proportions of chemical components, fusion zone, raw materials and many other factors. The importance of just a few of these factors will be discussed in connection with the actual photograph of such a slag.

One of the most important things to be considered is the composition of the slag itself. Most slags are made up of six main components; silica, alumina, lime, magnesia, iron, and sulphur. Thus, to begin with, to make slags complex we have all the variation of its six component parts. But there are still other things which also affect their appearance and may be added, such as the state of chemical combination with each other, melting points, fluidity, segregation, power of absorbing gases, oxidation, forces which will keep the components from combining with each other, forces which aid in the chemical reactions and so it goes that more and more complexities are drawn in to unravel their formation.

To discuss each one of these points would be a paper in itself, but a brief glance may be taken just to see how they affect the general appearance of the slag.

Silica gives slag its fluidity and is controlled by temperature and slag composition. In other words, it is easier for silica to be reduced and go into the iron with a large excess of silica than with a shortage of silica. This is due to the tenacity with which the bases hold on to the silica when there is but little present. A cold bottom always favors the silica going into the slag.

Alumina varies but little in actual quantity, with a uniform burden, but its actual percentage may change considerably due to the change of slag volume.

Lime is a very important component and since it may be changed at will holds an important position in the final determination of slags. But the lime exists in two ways, as silicate and as sulphide. The importance of the latter has been overlooked, but its bearing on slags will be discussed in a separate paper. Temperature, fusion zone, cold air, wind, etc., all determine whether the lime shall be combined with the sulphur or the silica. Above all, lime is most important since it is one of the main components which affect the driving of the furnace. Driving in turn controls the tonnage, so a broader knowledge of handling lime will be an advantage from this standpoint.

Magnesium seems to aid lime and act similar to it for when the lime goes down the magnesium goes up and often but little effect is noticed on a limestone carrying fairly high magnesium.

Iron is a temperature indicator and also an important factor in determining the condition of the sulphur. With low iron in slags there will be, generally, low sulphur in the iron, high iron in the slag means a cold bottom, free sulphur, and likely high sulphur iron. The important feature of the iron is that it does not exist as unreduced iron in the furnace, but is carried out mechanically as iron shot which when they come in contact with the air are burned to FeO coloring the slag black.

Sulphur is found as free sulphur and lime sulphide. The importance of the condition of the sulphur can not be overestimated. In very large furnaces large quantities of lime may be put on or taken off to remove the sulphur but unless the proper furnace conditions are also at hand the lime will do much harm rather than good. A furnace with a large part of its lime taken up by the sulphur may seem short of lime when by going cold the lime being freed from the sulphur makes an excess of lime with no actual change in the amount of lime on the burden.

The first general subdivision of slags must be made on temperature. Granting there has been no change of burden or other general furnace conditions and that the burden is regular and uniform, a cold furnace will produce very different looking slags from a hot furnace. Lime slags come out of the bottom of the furnace, hearth temperature is of vital importance when



it comes to the final condition of slags. For example the only difference between number 1 and number 20 might be a difference of hearth temperature.

Hearth temperature might be termed the chief factor in determining the final equilibrium between all the slag components. Various mixtures have various melting points; varying quantities of bases have strong or weak attraction on acids, depending on the temperature, and the melting point of the components.

The quantities of the different slag components determine their melting points. Slags high in silica and low in lime generally melt very early and are very fluid, slags high in lime and other bases are very thick, hard to heat up and melt at very high temperatures. For any given proportion of all the components there

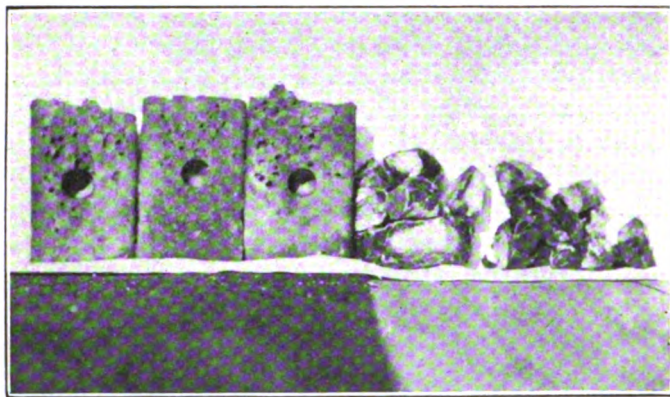


Fig. 1.—These slags illustrate types one, two and four.

must be a final point of equilibrium under the given furnace conditions. The segregation of the various combinations of these components is also effected by temperature, rate of cooling, etc.

The fusion zone is of extremely vital importance in determining the character of slags. With all conditions remaining constant a change of the position of the fusion zone will entirely alter the appearance of a slag. A low fusion zone with the proper amount of lime and heat means low sulphur iron and combined sulphur in the slag, a high fusion zone means higher sulphur iron, free sulphur, and a silicate slag.

Back of all the above features comes the quality of the raw material. This will determine the character of the slags permanently for an excess of any component will overshadow the effect of the rest.

Having discussed some of the general features which determine the character of slags, we are now ready to discuss some of the examples. See the illustration of the various types of slags, 1 shows a cold lean slag. This slag is glassy for two reasons—perhaps, the first because the bottom was cold, the second because there was an excess of silica. The most likely reason is because the furnace was cold for the slag is a brown glass and the brown color is caused by manganese which is a heat indicator. See

Figure 1, slag samples at extreme right illustrate slag of this type.

Illustration 2 shows a hot lean slag. The manganese has disappeared and the characteristic hot deep bottle green color is prominent. This type of slag might also look like the slag at the extreme right of figure 1.

Illustration 3 is a cream white lime silicate slag.

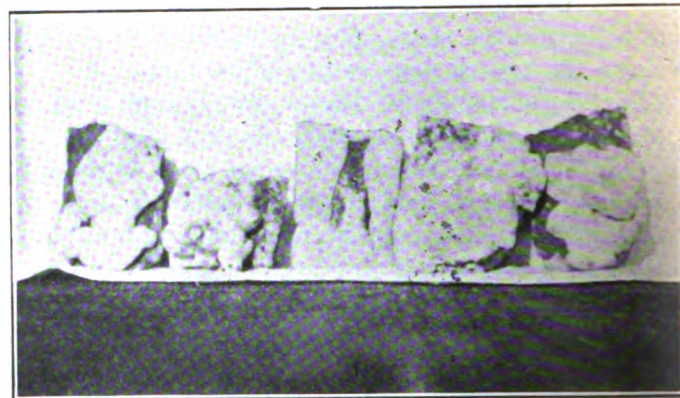


Fig. 2.—Snail shell like slags are hot bottom cold air slags. The appearance is caused by the gases escaping from the slag, making it creep into this form. See illustration 6.

This type of slag is a basic furnace slag with a very large slag volume. The large quantities of acid and basic components give it a very low melting point, hence an extremely low hearth temperature. The break is a cream white vitreous looking fracture, very

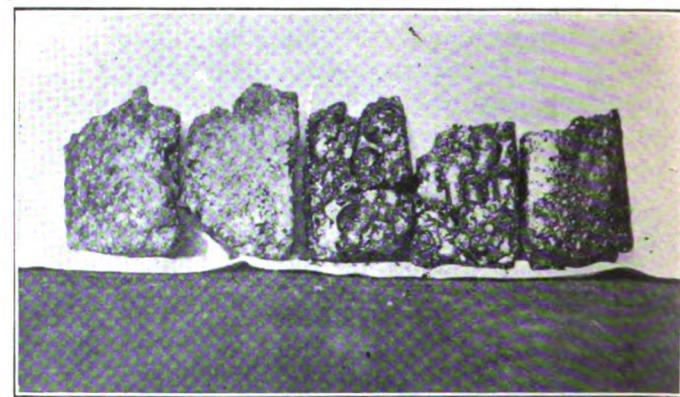


Fig. 3.—Types of slags shown in illustrations 11 and 12. The two on the left show a cold, limed slag; the three on the right show a cold slag from an overburdened furnace.

brittle, and the sample dipper would carry a thread.

Illustration 4 shows a medium hot slag. This fact is borne out by the green glass edge for cold glass slags are brown glass if there is any manganese present to amount to anything. This sample shows a very large excess of silica in the mother liquor of the slag and, in order of cooling, we find the silica had the lowest melting point, then the lime silicate separated out and, lastly, the alumina silicate in the middle. This type reproduced exactly is seen in the big sample



on the left side of figure 1. The illustrations are all made from actual slag samples.

Illustration 5 is a dark bluish gray, powdered or grain, foundry slag. This slag represents small slag volume, low silica, and it has a dry grainy appearance. In the middle is sublimed yellow sulphur due to a very large excess of sulphur in the mix which contained pyrites ore and also due to very high sulphur in the coke.

Illustration 6 is a typical hot bottom, cold air slag. This snail shell looking slag gets its appearance from the escaping gases held in the slag. The cold air keeps the sulphur from combining with the lime and it is car-



Fig. 4.—These slags show the type of slag of illustration 20. Note how near the middle samples correspond to the illustration.

ried out in solution in the slag. on coming into the air with reduced conditions of temperature and pressure the gases tend to escape, raising the slag in small shell like towers. Typical slags of this type are shown in figure 2.

Illustration 7 shows a hot alumina silicate slag. This is a foundry iron slag and is made on a hot bottom with a shortage of lime. The small amount of lime present has combined with the sulphur and the excess silica is taken care of by the alumina hence there is no white lime silicate as seen in illustration 4.

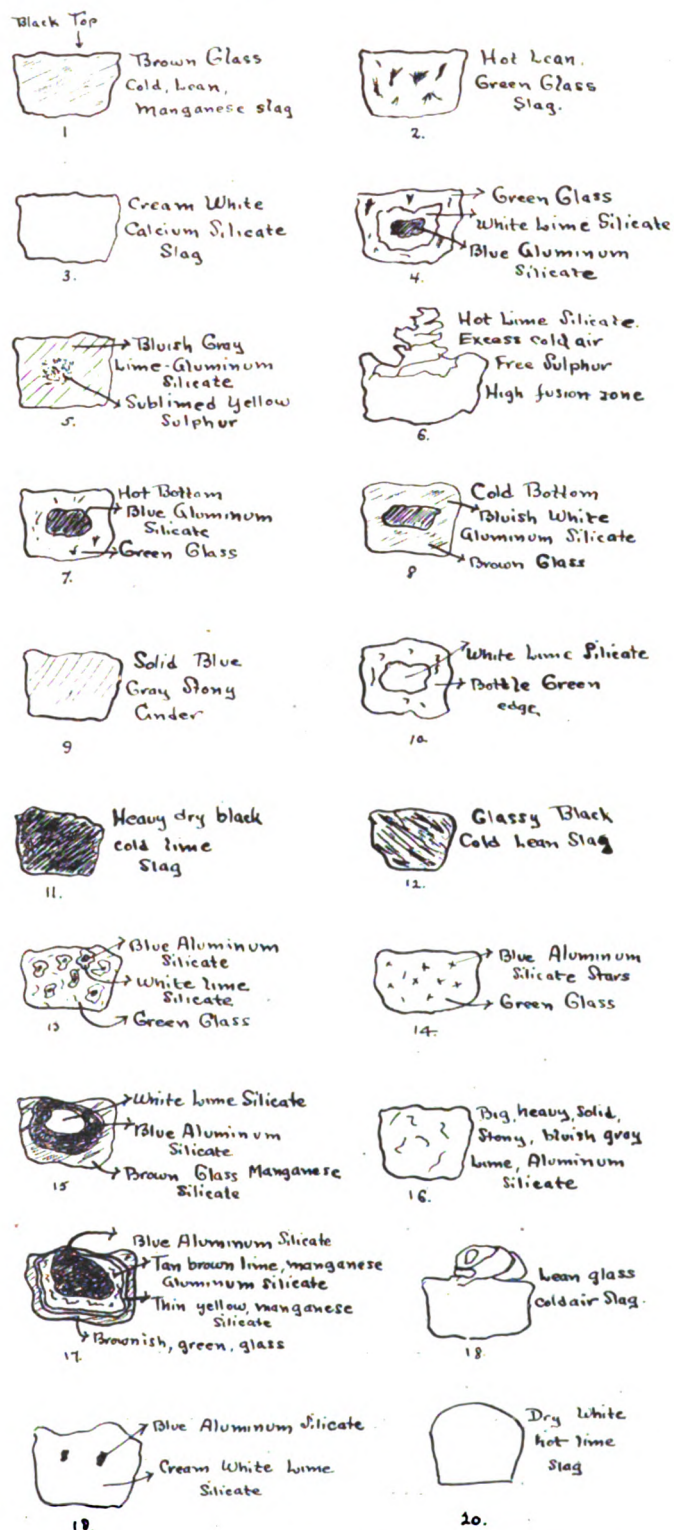
In illustration 8 the hearth is colder, hence the lime is free and instead of taking care of the sulphur it gives this alumina silicate a whitish appearance. Due to the drop in temperature the manganese has also gone into the slag and colored it brown. The whole slag is lean.

In illustration 9 both silica and bases are in about the same proportion, that is, there is not a large excess of either. The total quantity of both is not large in comparison to the rest of the slag and this, automatically, increases the alumina giving the slag its blue color. The stony appearance is due to the silica, for with the same bases and much less silica the same slag would be grainy.

Illustration 10 shows a hot lime silicate slag with

a shortage of lime. More lime would color the entire slag cream white but with the given temperature the lime present has been just sufficient to make the white

### Various Types of Slags.



lime silicate center. That the slag is fairly hot is shown by the lean bottle green edges.

The black heavy dry slag shown in illustration 11 is a typical slag of a cold, too heavily limed furnace. This type of slag makes extremely low silicon high

sulphur iron due to the fact that the extreme excess of bases on a cold bottom uses up every possible available bit of silica. The low hearth temperature leaves the sulphur free and the largest part of it poisons the iron. See figure 3, two lefthand samples.

The black slag of illustration 12 is a slag which is liable to turn up at any time in an overburdened furnace. The burden has been gradually increased until finally the furnace has spent itself and now the wind must be cut back a little, extra coke put in, or the burden lightened. Such a slag would immediately be cleared up by an increase of hearth temperature. See figure 3—the three right hand samples.

Illustration 13 brings out a type of slag a little more complex than the previous samples. Two things are prominent, an excess of silica and a moderately high hearth temperature. Considering the slag as a molten magnesia, the mother liquor has a large excess of silica. On being cooled it separated out first. Finally the concentration reached a state where the white lime silicate was formed and separated out and lastly the alumina silicate. This calls to view at once three temperatures or melting points, that of the green glass silica, that of the lime silicate, and that of the alumina silicate.

Slags of this type are open to a world of discussion for the writer is almost ready to believe from a period of close observation that lime and alumina combine independently of each other as silicates whenever there is enough silica to supply both; that the lime takes its supply first and what is left the alumina gets. This too is entirely a function of slag temperature and relative amounts of lime and alumina.

With a shortage of lime, fairly high temperature, and excess of silica the type of slag shown by illustration 14 is developed. Here the shortage of lime has developed the blue, alumina silicate stars. With a lower temperature in all probability these stars would be white lime silicate stars, but at the given temperature the equilibrium in the magnesia demands they be blue alumina silicate.

Were it not for the fact that all these illustrations had been drawn from actual slags the writer could think a mistake had been made in illustration 15. This slag does not seem to conform to the general run of slags, but the trouble is probably not with the slag but with the writer's inability to interpret it. In referring to notes made on this slag it was found that it was accompanied by almost tons of iron buckshot. That the slag is cold for its particular composition is shown by the brown manganese glass edges.

To explain the exchange of places of alumina silicate and lime silicate on cooling one might accept the following theory: The alumina silicate contained a large excess of silica, thus lowering its melting point while the lime silicate contained a large excess of lime and small amount of silica, thus raising its final

cooling temperature above that of the alumina silicate causing it to separate out last in the cooling of the magnesia.

Another complex relation is found in illustration 16. The amount of bases and alumina has been so large in proportion to the amount of silica that all seems to have had practically the same temperature of solidification. Thus when the slag chilled there was no separation of individual silicates, but all solidified together forming a heavy, dense, stony, blue, lime-alumina-silicate-slag. There are no marks of individuality of components but only a solid, homogeneous, massive, stony slag.

Illustration 17 brings in more components though it is not as hard to decipher as the previous slag type. The slag is cold for all components have the brown and yellow coloring of manganese. Stop just a minute and consider the relation that temperature bears to slag composition. The temperature for this slag is cold, though exactly the same temperature might be hot for the illustration below, 19. This is due to the complexity of the components together with a probably higher amount of bases present.

The segregation on cooling is excellently shown in this sample. Still a slight excess of silica is shown by the glass edge. Then next a very, very thin ring of yellow lime silicate colored very strongly by the manganese, finally the blue alumina silicate center.

Illustration 6 shows a type of slag which is caused by cold air. This slag had a fair amount of lime in it. The same feature on a lean slag is shown by illustration 18. The escaping gases blow the slag into large glass bulbs which when cold will be found to be hollow. A close observation of these bulbs on either a limy or lean slag will often show them to break before cooling, with the consequent escape of gas which may easily be seen.

The illustration of type 19 shows a large amount of lime and silica both, a consequent decrease of alumina and a fairly high hearth temperature. The proportion of lime is so large it has used up the silica entirely for there are no glass edges. On cooling the slag or magnesia was so proportioned that the main part of the magnesia was lime silicate. The large proportion of lime and silica automatically reduced the amount of alumina, hence only a couple of dots of alumina silicate.

The last type of slag, shown in illustration 20, is a white hot slag with heavy lime and high sulphur ores on a foundry furnace. This type of slag is a product of extremely high hearth temperatures with a dry mix on the burden and high sulphur ores. Such a slag on running emits heavy rolling white fumes and shows by its characteristics the high melting point of its components.

(Concluded on Page 122)



# Bessemer and O.H. Temperature Gaging

## Application of Known Pyrometric Devices to Measurement of Molten Iron and Steel Temperatures—Corrections to Be Observed for Accuracy.

By GEORGE K. BURGESS, U. S. Bureau of Standards.

The suggestion has often been made that it would be highly desirable, at least for certain grades of steel, to be able to control more certainly, by pyrometric measurement or otherwise, the temperatures of the operation of the open hearth and other furnaces used in the manufacture of steel and iron.

That the properties of the ingot and finally of the finished steel product are intimately related to the final temperatures attained by the metal in the furnace and to the temperature of casting, has been recognized by metallurgists for a long time, and this question has been very thoroughly treated, especially by Prof. Henry M. Howe, and by A. W. and H. Brearley.

It is the object of this paper to demonstrate that in so far as casting temperatures of furnaces, steel ingots, and similar operations involving the temperatures of streams of iron and steel are concerned, well-known pyrometric methods may be easily applied—if certain recently determined corrections are made and precautions taken—with a relatively high degree of accuracy. Greater but not insurmountable difficulties will be encountered in the case of open hearth furnace temperatures, while for those of the converter type a ready solution does not seem practicable.

It appears that certain essential data have always been lacking in reporting observations such as those of Le Chatelier in 1892. Thus the correction to be applied for the characteristic radiation—or emissivity—has hitherto not been adequately taken into account nor the limitations of the several possible pyrometric methods clearly recognized.

In view of the fact that, in open hearth practice the temperature to be measured in the furnace itself, in the stream of metal and slag and in the teeming into molds or ingots is usually above 1,500 deg. C. (2,700 de. F.) and may reach to above 1,750 deg. C. (3,200 deg. F.), it is manifest that we are limited to the optical and radiation types of pyrometer. Preference will be given to the former for the reason that the errors in the use of the radiation pyrometer caused by intervening gases, distance, size and specific radiation (emissivity) of objects sighted upon are greater and more uncertain than with the several forms of optical pyrometer using monochromatic light.

Although one may arrange to observe temperatures

of any portion of the open-hearth furnace, and also of the slag surface, what one is mainly interested in is the temperature of the metal, which bears but a remote relation to that of the roof and walls on which the heat of the fuel impinges.

Pyrometric control of temperatures of the roof is easy and may be exact and, although somewhat misleading, may also be made without serious interference from gases and smoke by sighting through suitably placed ports. With a knowledge of the melting range of the roof and arches, the wasting away of the bricks by overheating may be retarded by pyrometric control. Observation of temperatures within the furnace are simpler than of streams of metal or slag for no correction of any importance has to be applied to the optical pyrometer readings for selective radiation.

The temperature conditions in the bath of the open hearth furnace may perhaps be most easily determined by sighting an optical pyrometer through a peep hole in a door or through a port upon the surface of slag, preferably near the center of the bath. This temperature is not usually that of the metal but does not, in general, appear to be far removed from the metal temperature especially as the time of tapping the furnace approaches and the fuel supply has been fairly regular and uniform.

The temperature of the metal itself may be determined—but not as readily and surely as one could wish—by removing with a preheated spoon some 50 lb. and sighting upon the surface of the metal contained in the spoon with an optical pyrometer, taking a series of temperature-time readings and noting exactly the instant of withdrawal of metal and of temperature readings, from which data the temperature of the metal in the furnace may be estimated. Here complications arise, such as the slag residue and the formation of oxides on the surface, their solidification sometimes before the steel, and other surface effects dependent upon the condition of the steel, escape of gases, etc., with attendant uncertainties in temperature readings, the speed required in taking readings and other difficulties of rapid manipulation and operations, for which at least three persons are required, whereas one observer is sufficient in taking temperatures of furnace and slag.

Illustrations of all these methods of estimating furnace, metal, slag, and stream temperatures are given later on.

Abstract of technologic paper to be published by the Bureau, as appearing in the Transactions of the American Institute of Mining Engineers.

At present, no pyrometric method seems adapted to give satisfactorily the temperature of the metal in the Bessemer converter. The apparent temperature of the flames may of course be observed but this has yet to be shown to bear any definite relation to the metal temperature. There are fortunately other methods of recognizing the status of the reactions and the moment when a Bessemer heat is ready to cast.

If one can get a side view and within 50 ft. of the smoke free side of the tapping stream of an open hearth furnace or converter, accurate observations may easily be taken of its temperature. Even when sighting upon the stream from a distance good observations may be obtained. The observed temperatures here must be corrected for the emissivity or specific radiation of the metal or slag, a correction depending on the radiation which is characteristic of stream surface, and upon the colored light used in the pyrometer.

The greater brightness of the slag, readily noticed with the unaided eye, is caused by its higher emissivity and, also, in part, sometimes to the fact that it may be slightly hotter than the metal. Slag, however, is not a material of uniform composition nor is its brightness always the same from one cast to another at the same temperature. It follows that pyrometric estimations of slag-stream temperatures may be attended with considerable uncertainty.

Here we have almost ideal conditions for obtaining accurately the temperature of the stream, which is clean metal with a slight evanescent surface of oxide giving to the stream, viewed through red glass, a characteristic transparent appearance, the color of the metal being greenish and of the oxide yellow. The corrections to be applied to the temperatures for the emissivity of iron viewed in red light have been exactly determined.

The arrangement of the open-hearth or Bessemer mills is a considerable factor as to convenience with which temperature observations of furnace, tapping and teeming may be taken. Usually it is possible, however, to bring the pyrometer to within 10 ft. of the stream when teeming ingots; but distant observations—even to 100 ft. or more—may be taken with but a slight increase in uncertainty. These difficulties of pyrometer stations can usually be readily overcome. It is evidently necessary to have a portable apparatus that may be moved about while taking observations; and one that may be sighted from a considerable distance on a stream issuing from a 2-in. or 3-in. nozzle.

The observations here described were taken with the Holborn-Kurlbaum form of Morse pyrometer which has been frequently described; although, of course, other types of optical pyrometer might have been used. The outfit is portable and readily adjusted and permits taking temperature readings as fast as can be recorded. The instrument is calibrated so as

to give correct temperatures when sighting into a clear, closed furnace at uniform temperature, which approaches the theoretical condition of a "black-body," which is said to have an emissivity equal to unity.

When sighted on an incandescent, free surface having a specific radiation or emissivity  $e$ , always less than 1, its true temperature Centigrade  $t(=T-273)$  may be computed from its apparent (too low) temperature  $s(=S-273)$  by means of the formula.

$$\log_e e = \frac{c \log E}{\lambda} \left[ \frac{1}{S} - \frac{1}{T} \right]$$

where  $c = 14,500$ ,  $E$  the Naperian base, and  $\lambda$  the wave-length of light used in the optical pyrometer; here  $\lambda = 0.65\mu$ . This type of formula holds for any optical pyrometer using monochromatic light. The accuracy limit attainable in practice by this method is about 5 deg. C. at 1,500 deg. C.

The emissivity ( $e$ ) of a smooth surface of liquid iron free from oxide is 0.37 (for  $\lambda = 0.65\mu$ ) and no appreciable difference appears to exist between the emissivities of pure iron and of the steels containing considerable percentages of carbon, nickel or manganese, nor is there any appreciable variation of emissivity with temperature. A solid surface of incandescent iron—which has the same emissivity as the liquid—cannot be maintained free of oxide in practice; it is always the oxide which is observed. Liquid iron oxide has a somewhat higher emissivity, 0.53, than liquid iron and a very much less value than the solid oxide the emissivity of which is about 0.92. Liquid slag has a variable emissivity of uncertain limits depending on composition but probably usually ranging between 0.55 and 0.75, and 0.65 is apparently the usual value of  $e$  for "dark" slag. For reasons noted in Sec. IV, the emissivity of the metal stream of steel is taken as 0.40 instead of 0.37 in computing true temperatures below.

In the following tables are given certain typical series of observations—taken from among many obtained in several large steel plants during the past few years—of furnace and stream temperatures, including all the cases mentioned above. The attempt has not been made here to correlate the ingot or heat characteristics with the temperature, although some data have been accumulated on this subject. It is believed, however, that these observations demonstrate the possibility of obtaining accurate temperature observations for the establishment of any of the numerous correlations which may be suspected to exist; and it is also believed that these observations indicate the practicability of pyrometric control of open hearth practice, ingot casting, and similar operations.

Of course, the tracing out of the effect, say, of casting temperatures upon this or that ingot characteristic, presupposes the possibility of varying mill practice at will; and in any particular case, considering the



large number of other variables that may enter, it will probably take a carefully laid out plan involving a considerable quantity of metal—some of which will undoubtedly be scrapped—to accomplish the end sought. This is also a case where the experimental work has to be done on the same scale as in practice.

#### Observations in Bessemer Mill.

Table 1 gives the record of furnace casting and ingot teeming temperatures for 19 consecutive Bessemer heats of some 20 tons each of rail steel with a statement of the condition of the ladle as observed by the melter. The temperature estimation of the stream pouring from the converter may be rendered somewhat uncertain by the interference from smoke during the addition of spiegel, and to the intermittent presence of slag, and to the considerable distance from which the stream was viewed since the pyrometer was located on an opposite gallery adjacent to the ingot molds. The temperatures given in the table for pouring the converter, are each based on a series of observations taken after the addition of spiegel. It is assumed somewhat arbitrarily that the emissivity of this stream is 0.45, corresponding to a temperature correction of 119 deg. C. which gives an average converter pouring temperature of 1,595 deg. C. (2,903 deg. F.) which may be somewhat low. If these apparent temperatures were for a more strictly metallic stream ( $e = 0.40$ ) the true pouring temperature would be 1,623 deg. C. (2,953 deg. F.) on the average.

The teeming temperatures were more exact. Each temperature recorded is the average of several observations, usually 3 or 4, taken during the filling of an ingot mold of  $3\frac{1}{2}$  tons capacity, this operation occupying a time somewhat less than a minute. The emissivity of this stream is taken to be 0.40, which is probably exact to within 0.02 corresponding to a precision of 10 deg. C. at 1,500 deg. C.; the corresponding corrections to observed temperatures are uncorrected for emissivity; the average temperatures only are corrected.

The most striking facts these observations bring out are, the relatively narrow temperature range of less than 50 deg. C. within which the Bessemer converter may be and apparently must be operated, and the corresponding remarkable uniformity of ingot teeming temperatures.

#### Observations in Open Hearth Mills.

(a) Temperature of Metal and Slag Streams.—Table 2 shows the casting and teeming temperatures for a series of heats and top-poured ingots of rail steel from a bank of 60-ton basic open hearth tilting furnaces. As some 4 to 6 min. are taken in tapping such an open hearth furnace both the slag and metal streams may be observed, although it is necessary, on account of the pyrometer station being on opposite gallery, to wait for the smoke to clear away after ad-

ditions are made to the metal in the ladle. The emissivity of the metal is taken as 0.40, and if that of the (dark) slag is assumed to be 0.65, the slag and metal streams have on the average the same temperature of 1,607 deg. C.

As in the case of the Bessemer converter, Table 1, but a small variation in temperature from one heat to another is noticeable. The metal had its temperature lowered in the ladle by about 55 deg. C. before teeming and ingot 19 was cast on the average at some 35 deg. C. lower temperature than the first. The casting temperatures of the open hearth and Bessemer practice here shown are seen to differ but slightly.

The tapping and teeming temperatures for a series of heats of steel of various compositions from acid and basic open hearth furnaces in another steel plant showed the uncertainty of slag stream temperatures associated principally with the varying color of the slag. It was also demonstrated that all the heats were satisfactory and that the heat of the metal in each case was rated as "hot" which corresponded to a tapping temperature above 1,600 deg. C. and a teeming temperature between 1,550 deg. and 1,600 deg. C., whereas the teeming temperature of the Bessemer and open-hearth rail ingots of Tables 1 and 2 ranged very closely, about 1,525 deg. C. and 1,550 deg. C. respectively.

Very satisfactory detailed observations of the temperatures of tapping of several open hearth furnaces were taken by viewing the stream from the side with the pyrometer within 20 ft. of the tapping stream. It was noted that the heat may or may not be distributed uniformly through the metal in the furnace but the uniformity attained would seem to depend, in part at least, on the melter. Thus the temperature of the stream of one heat fell off some 80 deg. C. in the 2 min. of pouring; that of two heats remained reasonably constant; and the temperature of the stream of a fourth heat increased some 50 deg. C. showing that the top of the bath must have been considerably hotter than the bottom. The extreme range here observed in the true temperature of the metal in the tapping stream is 1,710 deg. to 1,520 deg. C.

In order to show how readily and accurately the temperature of a stream from a furnace, which is being tapped, may be followed, the actual readings taken for tapping heat 12  $\times$  36 are given in Fig. 1. The conditions of observing this tapping stream were less favorable, due to smoke, than usual. The fluctuations in pyrometer readings particularly at the start and finish are partly caused by intervening smoke. A piece of slag will give an occasional high reading. It will be seen that observations with the optical pyrometer may be taken easily at the rate of six or eight a minute. The observations on tapping another heat 13  $\times$  85 are also shown in Fig. 1.

The temperatures of miscellaneous operations in-

volving metal streams show that the average, corrected for emissivity,  $e = 40$ , for metal from a cupola is 1,394 deg.; for metal pouring from a 1,000-ton mixer, 1,372 deg.; for metal pouring into a 1,000-ton mixer, 1,396 deg.; for spiegel pouring into the ladle, 1,289 deg.; for recarbonizing iron pouring from small ladle, 1,287 deg.; and for blast-furnace iron going into open hearth mixer, 1,356 deg. The average values in each case have been corrected for emissivity on the basis that  $e = 0.40$ . All observations were taken with the Morse optical pyrometer.

(b) Open Hearth Furnace Temperatures.—Observations of temperatures of open hearth furnaces were made for some of the same heats as the casting temperatures of Table 2. The readings of the Morse and Féry pyrometers were corrected for instrument errors, but no correction was applied for emissivity or for absorption of radiation by the gases within the furnace. In the case of the Féry pyrometer, based on total radiation and calibrated in terms of the Stefan-Boltzmann laws the correction is much larger than for the Morse or other optical pyrometer. As the amount of gases in the various parts of the furnace varies from time to time, it was not practicable to make any correction for the absorption of these gases. The use of a total radiation pyrometer to determine furnace temperatures does not appear to be warranted.

Each furnace had three doors with openings through which the slag bath could be observed. The method of firing here used impinged the flames down on the bath surface so that the flames interfered quite seriously with obtaining satisfactory observations. The effect of intervening flames is usually to cause the pyrometer to read too high temperatures. Those taken with the optical pyrometer through the middle door were, however, fairly satisfactory. The furnace casting temperature and that of teeming of first ingot were taken for comparison.

An indication of the uniformity of heating the open hearth bath is seen by comparing the slag and metal casting temperatures with that of the slag surface as viewed in the furnace. Thus for heat 3  $\times$  98 the slag in the furnace attained the unusually high temperature of 1,700 deg. C. and maintained this for 20 min. up to 10 min. before tapping; the slag stream registered 1,621 deg. and the metal only 1,559 deg. The slag stream appeared to be usually slightly hotter than the metal and the relation of the two is undoubtedly dependent upon the details of methods of firing. In noting the considerable difference between furnace and slag stream temperatures, it is also to be remembered that the furnace cools very rapidly when heat is shut off, which often occurs several minutes before tapping.

In another heat the slag in the furnace registered 1,653 deg., the slag stream 1,606 deg. and the metal 1,625 deg.; in another heat the three temperatures were 1,635 deg., 1,612 deg. and 1,597 deg.; in another

1,610 deg., 1,659 deg. and 1,628 deg.

In Table 3 are given measurements of temperatures of an acid open hearth furnace, furnace heat which was followed in detail for 4½ hr. before tapping.

These three methods of observation were used: Sighting through small ports situated well to right or left corners of furnace, the pyrometer being directed toward middle back wall of furnace at arch and wall intersection; on the surface of 30 to 50 lb. of metal removed from furnace in a spoon; and on the slag in middle of the bath through peep hole in center door.

That the roof temperatures may have no relation to those of the metal is seen from the observations of heat 10  $\times$  90, for which the fuel was cut off for 20 min. immediately preceding casting and the temperature of the arch fell from 1,700 deg. C. to 1,378 deg. during the first 14 min., while the metal on the average remained above 1,585 deg., although the observations on the metal spooned out show that the metal at the top of the bath was cooling very rapidly from 1,640 to 1,520 deg. during those 20 min. of no heat being applied.

The temperatures of the arch are seen to be higher generally than the bath or metal temperatures, usually by some 50 deg. C., although there appears to be no definite relation, except that when the furnace has been clear for some time the bath and arch temperatures tend to become equal. All of these heats were rated as "hot" by the melter and the behavior of the metal in the molds was good.

The metal temperatures taken by observing the metal in a spoon were not as satisfactory as one could wish. They are not, however, inconsistent with the casting temperatures, and those of the bath when sighting on the slag surface.

There is some uncertainty as to the best value of emissivity to use for the clear surface (always greenish in color) of the liquid metal in the spoon. The value here taken is  $e = 0.40$ , but there soon develops a haze over the surface, probably of oxide, although a pronounced oxide surface, for which  $e = 0.53$ , will not usually form on a well skimmed, hot surface until the temperature has fallen considerably. It appears as if the oxide first formed by the air in contact with the very hot liquid metal is dissolved. It is possible that a value of  $e = 0.45$  for the emissivity of this surface would be more exact; the recorded "spoon" temperatures would then have to be lowered by some 15 or 20 deg. C.

The procedure followed for securing temperature determinations of the metal bath by means of observations on the surface of the metal dipped out in a spoon was as follows:

A place was marked on the floor near the open-hearth furnace charging door and the optical pyrometer sighted upon this mark at an angle of about 45 deg. and set to the approximate reading expected; a



spoon to hold 30 to 50 lb. of metal was first preheated, then filled with metal and placed on the mark; the metal was skimmed of slag with a single sweep of wood and the taking of temperature observations begun immediately. The instant of removal of spoon from the furnace was noted with a stop watch and of each temperature observation; also the condition of the surface, whether clear, hazy, oxide, slag, liquid or solid, quiet or boiling, or scintillating. Skimming the surface more than once had sometimes to be resorted to if the steel was not quiet, but with quiet metal the best results were obtained by leaving the surface intact after the first skimming and noting the formation of oxide and applying the emissivity correction for metal or oxide. Temperature observations can usually be begun within 12 sec. of removal of spoon.

**TABLE 1—Bessemer Mill.**

| Heat No.                          | Apparent Temperature of Metal Pouring from Converter | Temperature of Ingot Molds |       |             |       |       |       | Mean of 1-6 | True Temperature of 1-6 |
|-----------------------------------|------------------------------------------------------|----------------------------|-------|-------------|-------|-------|-------|-------------|-------------------------|
|                                   |                                                      | Apparent                   |       | Temperature |       |       |       |             |                         |
|                                   |                                                      | 1                          | 2     | 3           | 4     | 5     | 6     |             |                         |
| 29                                | 1,476                                                | 1,397                      | 1,377 | 1,377       | 1,389 | 1,369 | 1,367 | 1,379       | 1,500                   |
| 30                                | 1,472                                                | 1,401                      | 1,387 | 1,393       | 1,401 | 1,397 | 1,393 | 1,395       | 1,517                   |
| 31                                | 1,488                                                | 1,415                      | 1,419 | 1,403       | 1,393 | 1,383 | 1,375 | 1,398       | 1,521                   |
| 32                                | 1,458                                                | 1,397                      | 1,389 | 1,387       | 1,379 | 1,387 | 1,387 | 1,388       | 1,510                   |
| 33                                | 1,468                                                | 1,407                      | 1,401 | 1,407       | 1,405 | 1,403 | ..... | 1,405       | 1,529                   |
| 34                                | 1,454                                                | 1,417                      | 1,405 | 1,431       | 1,391 | 1,389 | 1,413 | 1,408       | 1,532                   |
| 35                                | 1,462                                                | 1,419                      | 1,417 | 1,403       | 1,393 | 1,405 | ..... | 1,407       | 1,531                   |
| 36                                | 1,490                                                | 1,434                      | 1,429 | 1,432       | 1,429 | 1,419 | 1,417 | 1,428       | 1,555                   |
| 37                                | .....                                                | .....                      | ..... | .....       | 1,383 | 1,372 | 1,397 | 1,384       | 1,505                   |
| 38                                | 1,490                                                | 1,385                      | 1,393 | 1,377       | 1,403 | 1,385 | 1,385 | 1,388       | 1,510                   |
| 39                                | 1,478                                                | 1,429                      | 1,403 | 1,393       | 1,389 | 1,379 | 1,377 | 1,398       | 1,521                   |
| 40                                | 1,486                                                | 1,424                      | 1,408 | 1,408       | 1,401 | 1,399 | 1,399 | 1,406       | 1,530                   |
| 41                                | 1,492                                                | 1,436                      | 1,401 | 1,375       | 1,389 | 1,424 | 1,399 | 1,404       | 1,528                   |
| 42                                | 1,468                                                | 1,408                      | 1,403 | 1,408       | 1,397 | 1,391 | 1,379 | 1,398       | 1,521                   |
| 43                                | .....                                                | 1,434                      | 1,419 | 1,409       | 1,407 | 1,389 | 1,372 | 1,405       | 1,529                   |
| 44                                | 1,488                                                | 1,433                      | 1,419 | 1,409       | 1,405 | 1,391 | 1,383 | 1,407       | 1,531                   |
| 45                                | 1,474                                                | 1,405                      | 1,405 | 1,405       | 1,403 | 1,401 | 1,387 | 1,401       | 1,524                   |
| 46                                | 1,462                                                | 1,383                      | 1,383 | 1,383       | 1,391 | 1,383 | 1,403 | 1,387       | 1,509                   |
| 47                                | 1,484                                                | 1,434                      | 1,432 | 1,417       | 1,413 | 1,413 | 1,409 | 1,419       | 1,545                   |
| Mean                              | 1,476                                                | 1,414                      | 1,405 | 1,401       | 1,398 | 1,394 | 1,391 | 1,400       | 1,523                   |
| Correction for emissivity .. 119  | 126                                                  | 124                        | 123   | 123         | 122   | 122   | ..... | .....       | .....                   |
| Mean true temperature, Centigrade | 1,595                                                | 1,540                      | 1,529 | 1,524       | 1,521 | 1,516 | 1,513 | .....       | 1,523                   |

Ladle Condition—Heat Nos. 29-31, spots; 32, spots—clean; 33, spots; 34-36, clean; 37, skull 4,000 lb.; 38-39, cut 1,500 lb. skull; 40, spots—cut 1,000 lb. skull; 41, clean; 42, clean—spots; 43-44, hot; 45, spots No. 1; 46, spots; 47, warmer—clean ladle.  $e = 0.45$  for converter metal;  $e = 0.40$  for ingot teeming.

The last two determinations in the spoon of metal temperature of heat  $12 \times 36$  of Table 3 are shown graphically in Fig. 2.

A comparison of the temperatures of several open hearth furnaces for a time of 3 hr. in various stages of melting was made, the observations being taken by sighting on the surface of the slag. There is apparently no great difference for the furnaces after melting has taken place, whatever the condition of the metal; the temperatures ranged from 1,567 deg. to 1,679 deg. C. and were usually above 1,620 deg. C. The bath temperatures, when they can be taken under conditions in which the flames from the fuel do not inter-

ferre, appear to give a fairly good indication of the temperature of the upper surface layer of the metal; if the stirring or heating has not been well done, however, the observations will be misleading if they are taken to apply to the metal as a whole.

The problem of temperature measurement and pyrometric control of furnace casting and ingot teem-

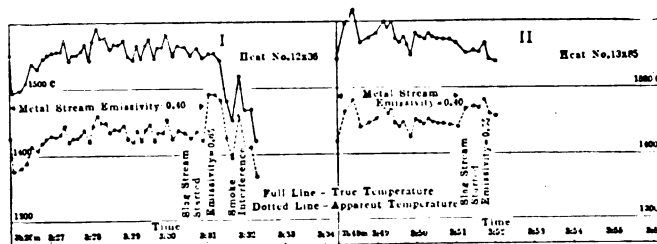


Fig. 1—OPEN-HEARTH TAPPING TEMPERATURES.

ing temperatures is shown, by a series of observations taken in several steel plants, to present no serious difficulties or uncertainties.

For this purpose the most satisfactory type of instrument is one of the optical pyrometers using monochromatic light and permitting observation from a distance of streams of metal.

It is shown that the necessary corrections to the observed optical pyrometer readings for emissivity of metal and oxides to give true temperatures, are sufficiently well known, but there may be uncertainty in the case of liquid slags.

For streams of liquid iron or steel the most pro-

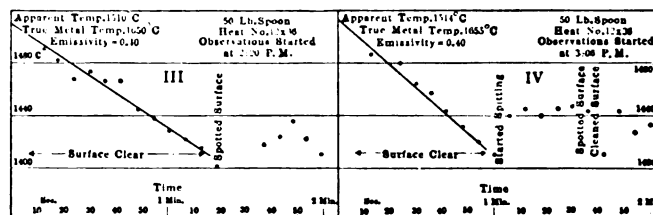


FIG. 2.—FURNACE TEMPERATURES BY SPOON METHOD.

able value of emissivity to take, with a pyrometer using red light of wave length  $\lambda = 0.65\mu$ , is  $e = 0.40$ , corresponding to a correction of 139 deg. for an observed temperature of 1,500 deg. C. The value of  $e$  for liquid slags is usually about 0.65 but varies with composition of the slag.

Determination of the temperature of the charge of Bessemer converters is not deemed practicable by pyrometric methods.

The operation of the open hearth furnace can be gauged by the pyrometer, it being possible to control readily the temperature of the roof and of the bath of metal and slag by observations taken through ports; and the temperature of the metal may be had at any instant, with a fair degree of exactness, by observation with the optical pyrometer of metal removed in a spoon. This operation is more certain with acid than with basic practice, the basic slag being more difficult to remove.

The temperatures of the roof of an open hearth furnace are shown to bear no necessary relation to that of the metal bath, which, it is again shown, may have zones of considerable differences in temperature depending upon the operation of the furnace.

The temperature of the roof of an open hearth furnace, dependent upon the firing practice, may vary rapidly and within wide limits, 1,550 deg. to 1,750 deg. C. The temperature of the open hearth bath is usually kept between 1,600 and 1,670 deg. C.

There is a remarkable degree of uniformity in casting temperature actually acquired by the melters in practice. Thus, for 19 consecutive Bessemer heats the teeming temperatures of the ingots were all between 1,500 deg. C. and 1,555 deg. C., and a similar degree of concordance, although at slightly higher temperatures, was found in the open hearth practice of several mills.

It is believed that a continuous, systematic following of the temperature, by the methods above outlined, of the various furnace and casting practices, on the part of steel and iron mills, would show the possibility of improvements, and greater certainty of production in quality of product; also changes and the effects of variation in ingot or furnace practice could undoubtedly be carried out with greater certainty than at present appears to be the case.

Several observers assisted in taking the above observations and acknowledgment for their help is due to Messrs. Crowe, Merica, and Waltenberg of the Metallurgical Division of the Bureau of Standards.

Acknowledgement of the opportunity of taking these observations is also gladly made to the management and members of the technical staff of the steel plants at Sparrow's Point, Md., Philadelphia and Bethlehem, Pa., and Washington, D. C.

TABLE 2.—Casting Open Hearth Furnaces and Ingots

| Heat No. | Furnace No. | Apparent Temperature of Pouring into Ladle. | Slag  | Hg't  | Low't | Molds | Apparent Temperature, Average. | True Temperature, Average.                                    | Remarks |
|----------|-------------|---------------------------------------------|-------|-------|-------|-------|--------------------------------|---------------------------------------------------------------|---------|
|          |             | Metal                                       |       |       |       |       |                                |                                                               |         |
| 5.....64 | 1,490       | 1,540                                       | 1,419 | 1,393 | 16    | 1,405 | 1,529                          | Spots                                                         |         |
| 3.....97 | 1,464       | 1,546                                       | 1,409 | 1,367 | 16    | 1,390 | 1,512                          | 800 lb. skull Melter during teeming said this heat poured hot |         |
| 5.....65 | .....       | 1,545                                       | 1,419 | 1,375 | 16    | 1,402 | 1,525                          |                                                               |         |
| 3.....98 | 1,431       | 1,554                                       | 1,421 | 1,403 | 19    | 1,410 | 1,534                          | 500 lb. skull                                                 |         |
| 4.....62 | 1,508       | 1,571                                       | 1,407 | 1,365 | 17    | 1,387 | 1,508                          |                                                               |         |
| 1.....32 | .....       | 1,466                                       | 1,393 | 21    | 1,420 | 1,546 | Clean                          |                                                               |         |
| 1.....25 | .....       | 1,530                                       | 1,448 | 1,389 | 22    | 1,407 | 1,531                          |                                                               |         |
| 2.....10 | 1,490       | .....                                       | 1,427 | 1,367 | 18    | 1,401 | 1,524                          | Spots                                                         |         |
| 3.....73 | 1,425       | 1,520                                       | 1,427 | 1,397 | 18    | 1,412 | 1,537                          | 500 lb. skull                                                 |         |
| 3.....74 | 1,429       | 1,572                                       | ..... | ..... | ..... | ..... | .....                          |                                                               |         |
| 4.....51 | 1,490       | 1,546                                       | 1,429 | 1,397 | 19    | 1,413 | 1,538                          | Spots                                                         |         |
| 1.....36 | .....       | 1,525                                       | 1,439 | 1,389 | 21    | 1,414 | 1,539                          |                                                               |         |
| 1.....41 | .....       | 1,527                                       | 1,457 | 1,410 | 19    | 1,414 | 1,539                          | Clean                                                         |         |
| 3.....80 | 1,478       | 1,546                                       | 1,450 | 1,397 | 20    | 1,411 | 1,536                          | New ladle spots                                               |         |
| 1.....42 | 1,516       | 1,545                                       | 1,448 | 1,389 | 19    | 1,414 | 1,539                          | Hot ladle spots                                               |         |
| 3.....82 | .....       | 1,532                                       | 1,424 | 1,383 | 19    | 1,402 | 1,525                          | Spots                                                         |         |
| 1.....43 | 1,468       | 1,532                                       | 1,415 | 1,375 | 19    | 1,392 | 1,514                          |                                                               |         |
| Mean     | .....       | 1,473                                       | 1,512 | 1,424 | 1,392 | 26    | 1,406                          | 1,530                                                         |         |

|                       |       |       |       |       |    |       |       |
|-----------------------|-------|-------|-------|-------|----|-------|-------|
| Emissivity correction | 134   | 66    | 127   | 122   | 26 | ..... | ..... |
| True temperature, °C  | 1,607 | 1,608 | 1,551 | 1,514 | 26 | ..... | 1,531 |

e = 0.40 for metal streams.  
e = 0.66 for slag.

TABLE 3.—Open Hearth Furnace Temperatures  
Acid Furnace No. 12, Heat No. 36.

| Oil from | Roof through Ports | Bath  | Spoon | Remarks                                        |
|----------|--------------------|-------|-------|------------------------------------------------|
| Left     | Right              | Slag  | Metal |                                                |
| R        | 1,647              | ..... | ..... | Pyrometer sighted over flames. Not melted yet. |
| R        | 1,666              | ..... | ..... |                                                |
| R        | 1,667              | ..... | ..... |                                                |
| R        | .....              | 1,623 | ..... | Bubbles appear dark.                           |
| R        | .....              | 1,602 | ..... | Slag bergs.                                    |
| R        | .....              | 1,627 | ..... |                                                |
| R        | 1,682              | ..... | ..... | Furnace stirred.                               |
| R        | 1,667              | ..... | ..... |                                                |
| L        | 1,694              | ..... | ..... | Oil reversed to left. About melted.            |
| L        | 1,727              | ..... | ..... |                                                |
| L        | 1,729              | ..... | ..... | On flames.                                     |
| L        | .....              | 1,655 | ..... | Black bubbles.                                 |
| L        | .....              | 1,566 | ..... | Reversed oil to right.                         |
| R        | 1,693              | ..... | ..... | Flames.                                        |
| .....    | 1,710              | ..... | ..... | Not on brightest flames.                       |
| R        | 1,694              | ..... | ..... | O. K. "Medium furnace."                        |
| .....    | 1,653              | ..... | ..... |                                                |
| R        | 1,687              | ..... | ..... | Uniform                                        |
| L        | .....              | 1,584 | ..... | Reversed oil to left.                          |
| L        | .....              | 1,618 | ..... |                                                |
| L        | .....              | 1,604 | ..... |                                                |
| L        | .....              | 1,672 | ..... | Metal quiet, few bubbles.                      |
| L        | 1,745              | ..... | ..... | Fairly uniform.                                |
| L        | 1,725              | ..... | ..... | Reversed oil. Charging hematite.               |
| R        | 1,710              | ..... | ..... | Fairly clear.                                  |
| R        | 1,710              | ..... | ..... |                                                |
| R        | .....              | 1,679 | ..... | Reversed oil.                                  |
| L        | .....              | 1,649 | ..... | Reversed oil.                                  |
| R        | .....              | 1,660 | ..... |                                                |
| R        | 1,648              | ..... | ..... | Clear                                          |
| R        | 1,640              | ..... | ..... | Clear.                                         |
| R        | .....              | 1,638 | ..... |                                                |
| R        | 1,626              | ..... | ..... | Clear                                          |
| R        | .....              | 1,601 | ..... | Slag bergs.                                    |
| R        | 1,633              | ..... | ..... |                                                |
| R        | .....              | 1,650 | ..... |                                                |
| R        | 1,628              | ..... | ..... | Clear.                                         |
| R        | .....              | 1,606 | ..... |                                                |
| R        | 1,627              | ..... | ..... | Clear                                          |
| R        | 1,660              | ..... | ..... | Charged ferrosilicon.                          |
| R        | 1,655              | ..... | ..... | Stirred furnace.                               |
| R        | 1,650              | ..... | ..... |                                                |
| R        | 1,674              | ..... | ..... | Flames.                                        |
| .....    | 1,638              | ..... | ..... |                                                |
| R        | .....              | 1,655 | ..... | Charged ferromanganese.                        |
| R        | 1,687              | ..... | ..... |                                                |
| R        | 1,702              | ..... | ..... | Flames. Hard tap lasted 5 min. Tapped.         |

Casting temperature 1,520 to 1,570 in 6 min. Stream viewed from smoky side.

## Types of Different Blast Furnace Slags.

(Concluded from page 116)

There are many, many, other types of slags but they all are developed in a systematic manner and are not a haphazard thing, as one might think. The general classification requires very close observation to separate the various types and bring home the fact more clearly that as many things on the furnace should be kept constant as possible. When many changes and a vast number of variables are introduced it makes it almost impossible to decipher the resulting slags.

Further discussion of slag characteristics will be presented in future articles on this subject by the writer.



# EDITORIAL

## The Railroad Problem.

Freight congestion has tied up so many cars that it is now almost impossible for the railroads to meet the more imperative need for the transportation of foodstuffs. Congestion in shipping centers, with the concomitant scarcity of cars in sections where daily shipments are imperative, such as steel plants and pig iron producers, is exercising a marked influence on industry, and in some cases even reducing the tonnage of products designed for use in providing more rolling stock to attempt to abbreviate the shortage—and so the tie-up goes around in a circle, with loss to every industry touched.

Last Christmas an attempt was made to alleviate the condition by shutting down a number of large producing plants for the holiday week, in the hope that this would permit the laggard railroads to catch up somewhat on their arrears—but what little effect this move might have had was discounted by the severe winter weather which followed, and which, by its effect on the steaming power of the locomotives, automatically shortened the maximum tonnage per train, and also shortened the mileage per car per day.

Figures show that a large percentage of the live freight, as well as a high percentage of that tied up on sidings and in terminal yards is iron, steel or their products; together with raw materials connected therewith. It then appears that, if the steel industry as a whole could arrange to give its several plants a week or ten-day shut-down for the annual overhaul which must come sooner or later anyway, it would withdraw over one-third of the daily fresh tonnage from railroads in the most congested district—and with the period of plant shut-down for a breathing spell in which to clean out the worst spots in the tie-up, the railroads ought to be able to get their rolling stock mobilized to carry normal traffic at the end of the time, and let the plants resume full production with some hope of being able to make shipments "at convenience of mill" rather than "at convenience of railroads," as has been the case in many instances for the past year.

The man who has to be urged to punch the clock to insure his getting to the job on time seldom has any punch left for performing his tasks.

One day's rest in seven is a necessity, but it does seem that the employer, in industries where continuous operation is imperative, should have the apportioning of the rest days among his men. And

it's a pretty safe bet that the judge who recently decreed that the worker should have the choice of his rest day would instantly reverse his decision if the same condition were brought home to him—in his kitchen, for instance.

It is still comparatively easy for a man with a Teutonic name to get work in a steel plant, but he is no longer given a job entailing human or material responsibility until he has been tested.

There is a steel plant making a corrugated sheet supposed to withstand all kinds of weather conditions which is using a composition roofing on some of its main buildings instead of its own product—what is the saying about a prophet being without honor?

A question in profits: If two million dollars must be spent to reduce handling costs for industries whose total capitalization is half a million, how profitable must the businesses be to pay legal interest on the investment. Ask Secretary Baker on the Pittsburgh bridge-raising project.

The British Hawkshaws at Halifax are going through the German ambassadorial party's belongings with a fine toothed comb, confiscating phonograph disks, cotton underwear and the like, but we have yet to hear of their commandeering any of the party's shoes on the ground that too many nails are contained therein—to the possible increase of Germany's steel supply.

For this Congress, it seems, the second class mailing rate is to remain unchanged, but it is not the fault of the mail order firms who want to post their direct-by-mail publicity at the expense of the national publications which they studiously avoid using. It's just another case of an interest posing as a public benefactor while the dear deluded public is really supposed to turn the stone while said interest grinds its axe.

When England shut down on Hadfields' and the shell order was returned to the United States the American plants were given the work; at a figure compromised on by Navy officials and steel plant executives—but only at a price where the patriotism of the steel makers involves a sacrifice of profits, and possible inroads on working capital, if conditions of manufacture become more restricted by labor, material or freight agencies.

# PRODUCTION TOPICS

## Suggestions Regarding Construction of Hot-Blast Stoves.

A hot-dry method of cleaning the gas from blast furnaces has been shown to conserve the sensible heat energy of the gas, and in general it thus permits of a higher flame temperature. The electrical method of cleaning gases removes from 98 to 99 per cent of the suspended matter in one operation when operating properly, thus making possible the use of a very clean gas for burning in the stoves. The use of such clean gas thus makes feasible a different type of hot-blast stove construction from that being used at present. It therefore seems advisable to construct the stoves from the viewpoint of getting the maximum amount of heat energy into the products of combustion.

By preheating the air added to the top gas and obtaining a better mixture of the air and top gas, less excess air will be required and a higher flame temperature obtained from the combustion of the top gas.

The interior of the stove should be provided with a kind of brick that will withstand a high flame temperature, will conduct the heat energy along certain directions, insulate the flow of heat along other directions and at the same time store heat energy so as to make the flow of such energy more uniform.

It is quite likely that these results can be best obtained by using several kinds of bricks: one type which is a good insulator of heat energy to be used for lining the stove and for making partitions through the stove to restrain the flow of heat; another type of brick or material with high refractory qualities; and a third type which will be a good conductor of heat energy.

The surface of the stove exposed to the atmosphere should be a minimum in comparison to the mass of checkerwork which it is possible to obtain, due regard being paid to other conditions.

With clean and hot furnace top gas it will be advisable to consider a rearrangement of the checker work in the stoves. One reason for the present size and shape of checker openings is to provide facility for periodical removal of coal dust. With clean gas the present wide spacing would not be required.

The mass of checker bricks should be as great as possible and still expose sufficient surface to the passing hot gases to absorb the greatest amount of heat, leaving the exit gases as cool as possible.

The checker openings should be small so as to bring the brick surfaces into intimate contact with the hot gases. The old rule that checkerwork openings must be 9 in. (due primarily to the necessity of cleaning the stoves of dust) can now be changed, and in fact has been changed in several plants.

The hot gases should be uniformly distributed across the cross-section of the passage and so maintained during their travel through the stove.

The hot gases should pass through the checker openings at a fairly high speed, thus increasing the heat transfer by the scouring action against the faces of the bricks.

The bricks should be so shaped and spaced as to insure the results mentioned above. It might even pay to have the bricks so close together as to require the installation of a fan above the stove to compensate for and overcome the additional friction of the gases through the smaller openings.

This greater resistance to gas flow in the stoves could be taken advantage of in insuring the best distribution, high gas speed adjacent to brick surfaces and maximum heat absorption.

The bricks should contain the greatest mass or weight of material per unit of volume, combined with the highest mean specific heat and heat conductivity; i.e., should be capable of holding the maximum heat energy consistent with speed of absorbing, storing and delivering such heat energy, and still possess the other qualities required of bricks for this purpose. Some experiments should be conducted and calculations made to determine the proper size, shape and composition of checker bricks, in the light of the points brought out in this paper.

Through improvements in design and the use of a hot-dry method of cleaning the top gas, it may be possible materially to lower the installation and the operating cost of the stoves, and obtain results equal to those obtained in present practice.

Mr. Mathesius' paper has shown several advantages resulting from increasing the temperature of the blast. It would seem that effort along the lines indicated above should be made to increase the temperature of the blast by obtaining hotter stoves through the use of higher flame temperatures. Success by this method should show a further marked reduction in coke consumption in the furnace, an increased output of iron, smoother running conditions, and an increase in the calorific value of the gas from the furnace.

As for preheating the combustion air for the stoves, this is somewhat analogous to preheating the blast for the furnace, but it is unnecessary to employ so expensive a method. The combustion air could be preheated by the stove exit gases by means of suitably designed heat-exchanging apparatus placed above the stove, the preheated air being delivered to the stove burners by means of fan and duct. Calculations readily show the importance of adopting this suggestion and should be proven in practice.

It should be noted that a higher efficiency of absorption can be obtained in the stove when the flame temperature is highest; the exit gases will be only slightly, if any, higher in the one case than in the other. Furthermore, perhaps the greatest advantage to be obtained by preheating the combustion air and by hot-dry cleaning will be the ability to get a hotter blast in the same length of time, thus improving the ratio of "time on wind" to "time on gas."

A burner for intimately mixing the gas and air before burning (a modified Bunsen type) will aid greatly in giving a high flame temperature and the gas will be burned with a much less excess of air. Forced combustion, consisting of properly blowing the air into a gas burner with sufficient pressure, insures quicker combustion and a larger stove capacity. Radiation losses might thus be reduced, since a smaller number of stoves would be required, provided the efficiency of heat absorption by the checkerwork is not impaired. The question of long flames versus flameless combustion should be answered by thorough practical tests.

For use in boilers the importance of thorough cleaning may in some cases be more important even than it is in the case of the stoves. In using raw gas it is customary to blow the dust off the tubes every day by means of compressed air or steam. During blowing, a large amount of excess air enters the combustion chamber. Immediately after clean-

ing, the dust begins to deposit again and the efficiency of the boiler immediately decreases. The cleaner the gas, the more valuable it is for boiler purposes. The hot-dry method of cleaning the top gas for burning in boilers is therefore more efficient than the wet method for the following reasons: (1) the top gas is made cleaner than when the wet method of cleaning is used; (2) the sensible heat energy of the top gas is conserved; (3) the temperature of the gases in the boiler is increased, making possible the use of a gas of lower calorific value; (4) no slags or corrosion results from the dust settling on the furnace bricks or the boiler tubes.

The curves described in our other paper in this Bulletin can be applied directly to calculations on the saving of heat energy in the boilers. In boiler operation there is the added advantage that the gas carried from the boilers is usually at a comparatively low temperature. For this reason the sensible heat energy of the unremoved moisture, carried away in the exit gases from the boiler, is even smaller than that from stoves.

The data on sensible heat energy given in the charts can be applied to a large number of problems: The heat coming from Portland cement kilns, smelter furnaces, cupolas, furnaces used to heat retorts for making illuminating, water and producer gas, coke ovens, etc. The electrical method of cleaning is now used in some of the above cases for removing the dust and fumes at high temperatures. At the Riverside cement plant and in sulphuric acid plants the electrical method is now being used to clean gases at about 900 deg. F. Several other gases have been cleaned at this temperature. A cheap and efficient method of cleaning gases at a high temperature will thus introduce a new epoch in the saving of the sensible heat energy that is now being wasted in so many instances.

#### Pulverized Coal as Fuel.

It is stated by H. R. Banhurst, in Metallurgical and Chemical Engineering, that coal properly pulverized and burned may be made to yield higher economic results than are attainable by any other means. The proper conditions are: (1) The coal must be dried to not exceeding 1 per cent of moisture. (2) It must be pulverized to a high degree of fineness. (3) It must be projected into a chamber hot enough to cause instant deflagration. (4) It must be supplied with air sufficient to yield the oxygen necessary to burn the carbon at once to CO<sub>2</sub>. These four requirements are discussed in detail, with special attention to (3) and (4), which have hitherto not been sufficiently considered by engineers. Very high temperatures are attainable with pulverized fuel; thus

|                                      |                     |           |
|--------------------------------------|---------------------|-----------|
| 1 pound carbon with 11.6 pounds air  | Normal              | 4,859° F. |
| 1 pound carbon with 13.92 pounds air | 20 per cent excess  | 4,102° F. |
| 1 pound carbon with 16.24 pounds air | 40 per cent excess  | 3,550° F. |
| 1 pound carbon with 18.56 pounds air | 60 per cent excess  | 3,129° F. |
| 1 pound carbon with 20.88 pounds air | 80 per cent excess  | 2,797° F. |
| 1 pound carbon with 23.20 pounds air | 100 per cent excess | 2,529° F. |

In practice the fireman soon learns how to judge whether the fire is hot enough by its color and the length of the flame. The better the conditions, the shorter and whiter the flame will be. The temperature is generally kept down to the limit desired by admitting excess air. With regard to protecting the furnace lining against the destructive effect of these high temperatures, much of the trouble has arisen from the gases impinging on the surface walls at points where the direction of the gas travel changes, and from too high velocity of the gases due to contracted ports. If the greater part of the heat is largely absorbed by the charge, the waste gases will be proportionately less active in scouring the brickwork. In almost any construction, except perhaps a rotary kiln, it is necessary to change the direction of the gases on their passage to the flue. This change of direction causes the gases to impinge upon the diverting bricks with an energy

proportional to their velocity. At these points the brick can be protected by a system of water-cooled pipes embedded in the walls. The brick may frit to some extent until the protected area is reached, when the fritting will be arrested. The surprisingly small quantity of water which it is necessary to introduce to keep the temperature of the outlet below 200 deg. F. proves that the cooling effect is limited to a prevention of cumulative action, and is no perceptible drawback to the efficiency.

#### Smokeless Operation of Heating Furnaces.

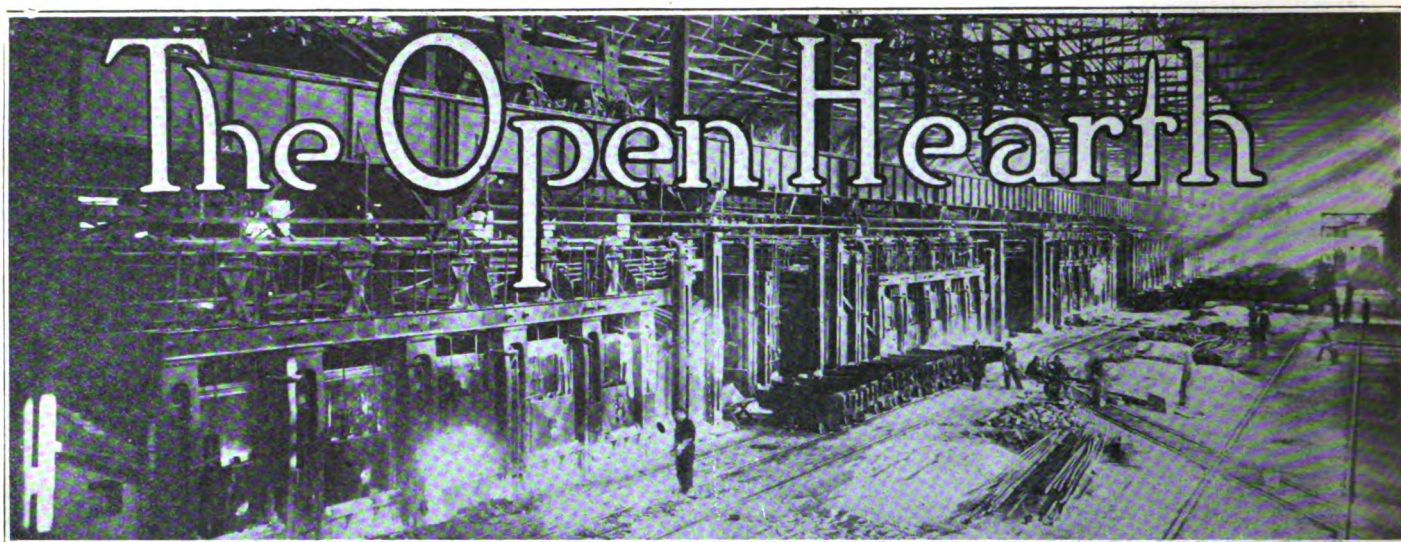
Smokeless operation of heating furnaces is scouted by many of the older sheet mill foremen—they say that a smokeless furnace will burn or blister the steel; especially when large pieces are being heated—and they therefore insist that furnaces in their shops be run with a smoky flame, so that conditions cannot be oxidizing. This is all very well where fuel costs are negligible—and where there is no smoke inspector on the alert constantly—or where the inspector is fond of cigars or other pacificators. But in the larger industrial cities there is an ever-growing respect for clear skies, and the smoke inspector cuts a hole into possible profits when he puts across convictions for smoke ordinance violations.

With an intelligent furnace operator practically smokeless conditions can be obtained if two things are watched. The fuel must be allowed to burn completely before the gases come into contact with the steel being heated, and the air admitted to the furnace must not be cut too low. In heating large stock it is usually possible to design the furnace so that combustion can be completed before the gases reach the hearth, or if not a series of baffles can be introduced to give the necessary length to the flame travel. It then remains to see that the furnace tender is supplied with some kind of check upon his furnace operation.

In one plant where these conditions are sought and smokeless operation of a furnace is rewarded by a cash consideration in the pay envelopes of the careful furnace tenders, it was early realized that the furnace man must be able to tell the condition of his stack before he could judge whether or no his furnace was outside the law. But it was obviously impossible for the tender to be running outside of the plant every few minutes to see if his stack was smoking; so there was no remedy left but to bring the stack to the operator. And for this a modification of the submarine's periscope was fitted. Under the protecting shelter of roof monitors small mirrors were placed, at the top of tin tubes terminating near the charging side of each battery of furnaces. At the base of the tube was placed a second mirror, adjustable to throw its reflection as desired. The mirror was then encased in a conical "see-scope" as the men dubbed it, so that the reflected light from above would be all that reached the mirror directly. By glancing in this mirror the workman could instantly see just what his stack was doing, and could regulate the air and fuel accordingly—this plant was using at this time powdered coal for heating its large furnaces—without being expected to go out into the weather to check up conditions.

The smoke inspector rather scoffed at the plan of periscopes, but after one of his deputies had watched the plant for a whole week without getting a single violation of the smoke ordinance, he began recommending the periscope plan to some of the persistent offenders in his district. The only expense connected with the plant is that of the two mirrors and the connecting tube and the slight trouble of getting the tube straight. After the device is installed the furnace man can watch his work at the fire door and at the chimney top, and thereby double check the combustion he is securing.





Samuel Adams, who has been connected with the Sharon, Pa., plant of the American Sheet & Tin Plate Company, on February 15 became hot mill superintendent for the McKeesport Tin Plate Company, McKeesport, Pa.

V V

Norton H. Anderson, superintendent of manufacture for the Bethlehem Steel Company, South Bethlehem, Pa., has resigned.

V V

O. F. Bishop, for the past fourteen years connected with the LaBelle Iron Works, Steubenville, Ohio, as superintendent of the blooming and skelp mills has resigned to become associated with the steel department of the Midvale Steel & Ordnance Company, at Coatesville, Pa.

V V

H. A. Brassert, former superintendent of blast furnaces, Illinois Steel Company's South Works, South Chicago, Ill., has been made assistant general superintendent, succeeding P. A. Newton, promoted.

V V

Ernest G. Burns, for fourteen years connected with the LeBelle Iron Works, Steubenville, Ohio, as chemist and latterly as chief chemist, has entered the laboratory of the United Alloy Steel Company, Canton, Ohio.

V V

Murray M. Duncan, general manager of the Cleveland-Cliffs Iron Company, Cleveland, Ohio, has been elected vice president of the company succeeding J. H. Sheadle, deceased. He will be in charge of mining operations and will retain his general manager's office at Marquette, Mich.

V V

J. S. Green, who has been master mechanic for the Franklin Steel Works, Franklin, Pa., of the Chicago Railway Equipment Company, has resigned to accept work connected with the installation of the new plant of the Wickwire Steel Company, Buffalo, N. Y.

V V

Charles F. Grubb, for eight years connected with the Cambria Steel Company, Johnstown, Pa., and a like period with the Lorain, Ohio, works of the National Tube Company, is in charge of the reheating furnaces of the Minnesota Steel Company, Morgan Park, Minn., instead of Frank Powers, as was announced erroneously in the January issue of THE BLAST FURNACE AND STEEL PLANT.

V V

W. S. Hall, formerly special electrician, becomes electrical engineer of the South Works, Illinois Steel Company, South Chicago, Ill., vice R. Tschentscher, resigned.

G. N. Herman is now secretary to the general superintendent of the Illinois Steel Company at the South Works, South Chicago, Ill., vice D. V. Medalie, resigned. He was formerly chief clerk of the construction department.

V V

John Hoffman has been made master mechanic at the Midland, Pa., plant of the Pittsburgh Crucible Steel Company, vice C. A. Harper, resigned.

V V

R. W. Jackson, who has been connected with the Illinois Steel Company at its South Works, South Chicago, Ill., since 1915, has been put in charge of the company's pyrometer laboratory.

V V

Elmer Kechler, chief engineer of the Franklin Works of the Chicago Railway Equipment Company, located at Franklin, Pa., has been made master mechanic, vice J. S. Green, resigned.

V V

C. W. Lutz, who has been superintendent of the Fairfield, Ala., plant of the American Steel & Wire Company, has been transferred to Pittsburgh, to become assistant manager of the plants there.

V V

Stewart M. Marshall, formerly chief engineer of the Cambria Steel Company, Johnstown, Pa., and latterly chief engineer for the Southwark Foundry & Machine Co., Philadelphia, Pa., has formed a partnership with Charles Page Perin, to undertake consulting work connected with the iron and steel industry, with offices located at No. 2 Rector Street, New York City.

V V

W. Mathesius, who has been assistant blast furnace superintendent at the South Works of the Illinois Steel Company, South Chicago, Ill., has been made blast furnace superintendent, succeeding H. A. Brassert, promoted.

V V

E. V. McKay, acting superintendent of the North Lebanon, Pa., furnace of the Bethlehem Steel Company, will remain in an advisory capacity.

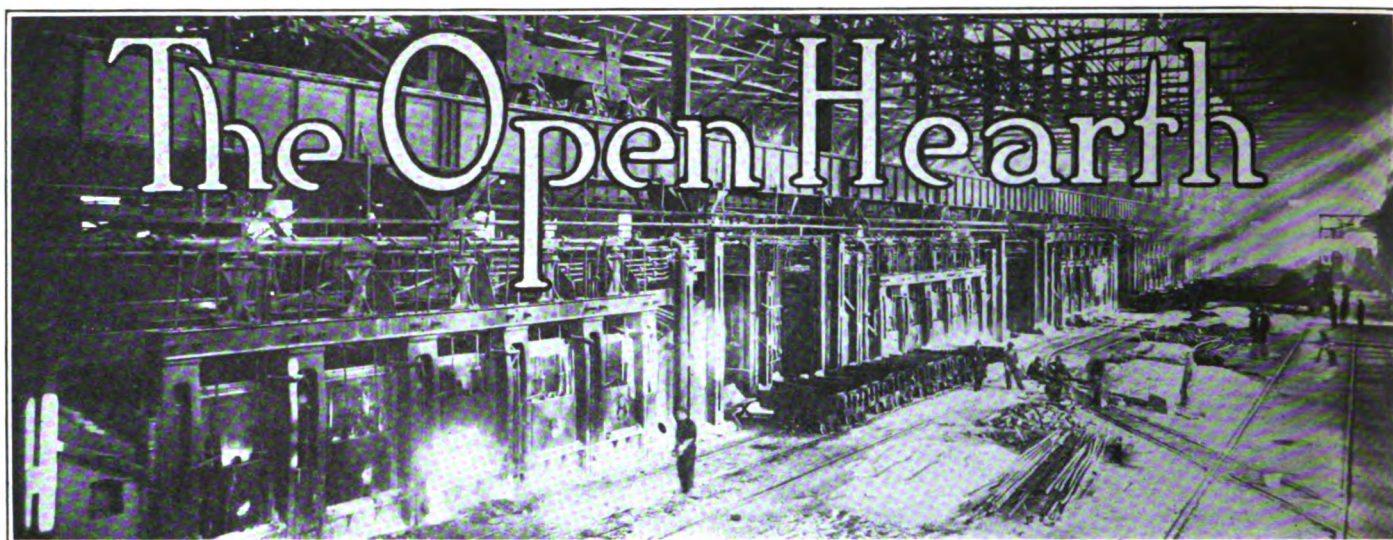
V V

D. V. Medalie, secretary to the general superintendent of the South Works of the Illinois Steel Company, South Chicago, Ill., has resigned.

V V

P. A. Newton, assistant general superintendent, becomes general superintendent of the South Works, South Chicago, Ill., Illinois Steel Company, vice W. A. Field, resigned.





Harry O'Connor, formerly connected with the DeKalb, Ill., plant of the American Steel & Wire Company, becomes superintendent of the Anderson, Ind., plant, vice Thomas D. Temple, transferred.

V V

S. Coles Peebles has been made general manager of the Ashland Iron & Mining Company, Ashland, Ky., and will have charge of the steel plant now under construction by that company.

V V

Charles Page Perin, for sixteen years consulting engineer in New York City specializing on engineering problems connected with iron and steel production, has formed a partnership with Stewart M. Marshall, with offices at 2 Rector Street, where consulting work on iron and steel production problems will be undertaken.

V V

A. L. Roberts, formerly designing and mechanical engineer for the Crown Cork & Seal Company, Baltimore, Md., has resigned to become designing engineer in the construction department of the Bethlehem Steel Company, South Bethlehem, Pa.

V V

George Smart, for the past twelve years editor of the "Iron Trade Review," Cleveland, Ohio, has resigned to become associated with the editorial staff of the "Iron Age," New York City. He is well and widely known for his contributions to iron trade journalism. He is a member of the American Iron & Steel Institute.

V V

J. V. Schrock, for the past twelve years chief at the Union Works of the Carnegie Steel Company, Youngstown, has been made chief clerk of the entire Youngstown district of the company.

V V

Charles J. Stark, connected with the publication since 1907, has been made editor of the "Iron Trade Review," Cleveland, Ohio, vice George Smart, resigned. He has been in charge of the New York office of the Penton Publishing Company since 1910.

V V

Philip J. Stremmel, connected with the Niedringhaus plants at Granite City, Ill., for 17 years, operated as a part of the National Enameling & Stamping Company, has been made general manager.

V V

Ralph H. Sweetser, recently announced as having opened offices as consulting engineer at Easton, Pa., has become

works manager of the Columbus Iron & Steel Company, Columbus, Ohio. He was blast furnace superintendent for that company before becoming president of the Thomas Iron Company, Easton, Pa., which he relinquished to open consulting engineer's offices as noted.

V V

Thomas D. Temple, plant superintendent for the American Steel & Wire Company at Anderson, Ind., has been transferred to Birmingham, Ala.

V V

L. A. Touzalin, assistant superintendent of blast furnaces 1-E, South Works of the Illinois Steel Company, South Chicago, Ill., has been made assistant blast furnace superintendent, vice Walter Mathesius, promoted.

V V

R. Tschentscher, who has been connected with the Illinois Steel Company, South Chicago, Ill., for the past thirteen years, has resigned to become general superintendent of the steel plant for the Keystone Steel & Wire Company, Peoria, Ill. The steel plant of this company, to consist of open hearth furnaces and blooming, billet and rod mills, will be ready for operation shortly.

V V

E. W. Tutwiler, formerly general superintendent of the Tata Iron & Steel Company, Sakchi, India, has been made general manager of the entire plant, vice Barton R. Shover.

V V

John Weichert is now assistant supervisor of labor and safety, Illinois Steel Company, South Works, South Chicago, Ill., vice Thomas H. McKenney, promoted.

V V

F. H. Willcox, metallurgical engineer with the U. S. Bureau of Mines, and located at the Pittsburgh branch, has resigned to become associated with the Huessener Engineering Company, Inc., with offices at 1405 Oliver Building, Pittsburgh, Pa.

V V

John C. Williams, formerly assistant to the president of the Phillips Sheet & Tin Plate Company, Weirton, W. Va., who has been connected with the company since its incorporation eleven years ago, has been elected third vice president, in charge of the operating department.

V V

W. Lloyd Wolfe, who has been superintendent of the Lackawanna Iron & Steel Company's plants since 1908, has been made general superintendent of the Bethlehem Steel Company's blast furnaces and coke-oven plant at Lebanon, Pa.



# Some Pointers on By-Product Coke Oven Operations

## THE CAKING POWER OF COAL.

(Concluded from last month.)

Coals, in which the property of caking is strongly developed, are restricted as far as their industrial application is concerned.

For the proper combustion of the fuel in a blast furnace or cupola, it is absolutely essential that a satisfactory blast shall traverse the body of the charge. The use of a caking coal is quite prohibited for such purposes, owing to the fact that the coal rapidly agglomerates into a mass so compact that the free passage of the blast through its body is seriously impeded. Even with a coal of moderate caking power, there is a great possibility that what is termed "scaffolding" may occur in the furnace. This means that an agglomeration of material attaches itself to a particular part of the furnace, and consequently does not descend regularly with the rest of the charge. Considerable danger may be incurred when the support fuses and the "scaffolding" suddenly descends.

A mixture of caking and non-caking coal may be used for many purposes. The object of admixing the non-caking coal is that it prevents the charge binding itself into an impervious mass. It is recorded that in the South Wales copper smelting works such a mixture is used and is found to be quite effective.

As may be expected, the great demand for caking coals is for the manufacture of coke.

Non-caking coals have a much wider application than the caking variety. A non-caking coal, called "splint" coal, and which would be classified as a flaming coal, is used instead of coke in some of the blast furnaces in the West of Scotland. A few furnaces in Staffordshire also use a similar non-caking coal, which is also eminently suitable for the manufacture of pottery ware.

Non-caking coals, rich in carbon, are in great demand as "steam" coals, and huge quantities are used in engines. The best varieties, owing to their smokeless combustion, are used largely in the navy of this and many other countries.

For household use an absolutely non-caking coal is not always recommended. With such a coal the fire develops far too intense a heat and the coal is rapidly consumed. A coal having a tendency to cake slightly is probably more suitable in that the rate of burning is reduced to a reasonable amount.

For a considerable time the slack of non-caking coals was regarded as waste material; but many methods have been suggested for producing a coke of commercial value from such types of coal.

Non-caking coals may be divided into two classes: first, non-caking coals with a low fixed carbon content (flaming coals); second, those containing a high percentage of fixed carbon (steam coals and anthracites). Obviously, for the preparation of coke, the latter are more suitable as the yield will be larger. All that remains to be done is to find a material which will firmly cement the particles of the non-caking coal into a coherent coke. Many proposals to effect this requirement have been forthcoming, and numerous patents have been granted on this subject. Generally, carbonaceous matter has formed the agglomerative material, but earthy matter and salts have been suggested. The latter have met with no success, owing to the high ash content of the resulting coke.

Two of the methods of utilising non-caking coal-slack in the production of coke will be considered.

(1) By Mixing with a Caking Coal.—The method of preparing a firm coherent coke from a mixture of a non-caking and a caking coal was first patented in 1850. Since this date numerous modifications have been patented, but the general idea is the same in each. Of course, the proportions in which the coals are mixed cannot be fixed, because the quantity of non-caking coal will depend largely on the caking power of the caking coal. If it is large, the caking coal will be able to bind a correspondingly large quantity of the non-caking coal into a firm coke. Trials on a small scale, using varying proportions of the constituent coals, must be made until a suitable coke is obtained.

It was at first asserted that it was essential to powder finely the non-caking coal, but experience and subsequent tests have appeared to show that the contrary is true. That is, it is beneficial to crush the caking coal, while the non-caking coal need not be so finely divided.

As early as 1869, Vériot and Till-Appolt published, in the *Bulletin de Société de l'Industrie Minérale*, an interesting research on preparation of coke from a mixture of anthracite and caking coals. In their paper—"The Carbonisation of Anthracite or Lean Coal (*Houilles maigres*)"—it is stated that the finer the caking coal is powdered the less of it is required to cement the particles of anthracite into a coherent mass. A firm coke was obtained by using a mixture of one part of finely ground caking coal and four parts of moistened anthracite, the particles of which varied in size from a pea down to a quarter of that volume. The caking coal seemed to form itself into a paintlike layer over the surface of the particles of anthracite. It was therefore considered that, if the anthracite particles were more finely divided, the surface area would be so increased that there would be insufficient caking coal to cover it. During the process the particles of anthracite appeared to be unchanged and could be seen in the coke as shining grains which showed no signs of fusion. As a conclusion to the research, it is suggested that the two coals must be ground separately and then mixed in the required portions. If this is not done, and the two coals are powdered as a mixture, the caking coal must form at least one-third of the quantity, in order that good coke shall be produced.

(2) By Mixing with Pitch.—Many patents have been obtained for using a mixture of pitch and coal in the preparation of coal; but, as a good market for pitch had been found abroad, little of this produce was available for the development of this method. In October, 1914, it was reported in a *Bulletin of the Commercial Intelligence Department of the Board of Trade* that, during the year 1913, pitch to the value of one million pounds sterling was exported from Great Britain largely to France, Belgium, and Italy. The chief use of the pitch in these countries was for the manufacture of briquette fuel; but during the European War most of the industrial areas and coal-producing districts of these countries have been in the possession of the enemy. In consequence, the export of pitch has ceased entirely, and large stocks of this product commenced to accumulate at the tar distilleries. Attempts therefore were made to utilise this pitch, and among these this method may be mentioned.

In the first, pitch mixed with a coal which is either non-caking or only moderately caking, and the mixture is used in the manufacture of coke. It is claimed that a good coke is obtained.



# INDUSTRIAL SAFETY

## Health and Safety. By Dr. E. R. HAYHURST.

This being a new country, we have misled ourselves into believing that we have no retrograde conditions. In the matter of hygiene and sanitation of work, we have, indeed, been very slow to realize how much efficiency and production depend upon just these three things:

Work place, workers' health, and workers' knowledge of how to preserve their health.

A state-wide survey of these features in Ohio, in which over 1,000 establishments, employing 235,000 wage earners, were covered, showed to an astonishing degree the limited state of perfection which exists in these matters.

Every employer should endeavor to intensify the output in his plant by a careful attention to these hazards. He not only needs a work place in which each physical hazard of the environment is standardized, but one in which the principal physical and mental defects in his workers are known and compensated for by a selection of the worker to the job to the worker.

Further than this it must not be forgotten that the most perfect specimen of Apollo placed within the most exemplary environment, may soon prove a decidedly bad risk if he has no knowledge of how to take care of himself and his health, and is given no instruction in the same. Such knowledge is not born in persons, at least no more than a savage needs for his simple, wild life. One glance shows that this is not enough for the many hazards imposed by civilization.

The real activator, in bringing about this higher degree of efficiency and its associated economics through industrial hygiene, consists in some form of health insurance whereby the employer, employe and an intelligent social or state interest are all working toward the same end and in which the dollar paid toward premiums against sickness, waste and loss of efficiency is not a small incentive.—"The Dodge Idea."

In an effort to lower the number of "compensation cases" at their mines and thus to lower their premium rates, local operators are putting into effect many new safety-first ideas. The Dodson companies, operating collieries at Weston, Beaver Brook and Morea, have appointed one miner, one inside company man, one outside company man, the different foremen and the colliery superintendent as a colliery safety-first committee at each of their mines. The three superintendents in turn report the result of their work to the general superintendent. Eight first-aid teams and a visiting nurse are supported. The men resent the loss of time for what seems to them a trifling injury, but records show that it is a good practice to keep these men idle in order to safeguard them from infection.

There is a stringent rule in our plant, says a Youngstown Sheet and Tube Bulletin, that cars being loaded, unloaded and under repairs must be protected by blue flags during the day and blue lights at night. These flags or lanterns can only be removed by orders of the foreman, who placed them, or the foreman who succeeds to the job. On October 8th, there were three cars being unloaded; they were protected by the regular blue lights. A member of a railroad crew took the lights away without authority and coupled onto the cars. Fortunately no one was injured; that, however, was not the fault of the trainman. This man is no longer in our employ.

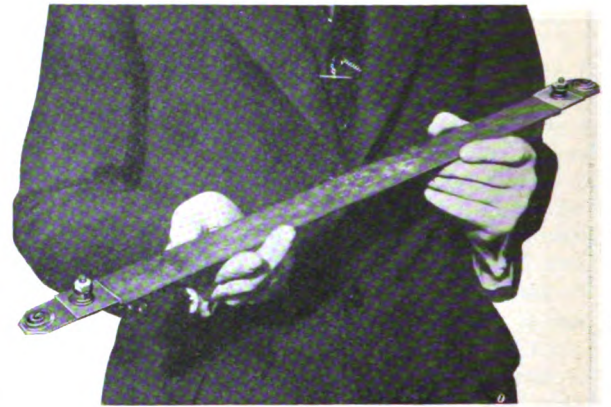
He was discharged. We want no man to work for us who has so little regard for the life and limbs of his fellows.

A safety suit for a workman which will enable him to pull himself free in case of such an accident has been recently devised by H. P. Andrews of Portland, Ore. Instead of being sewed together, snap hooks are used. It answers all the demands for ordinary wear, but in case any portion of the workman's clothing is caught in the machinery, the ordinary pressure which would be exerted in endeavoring to make his escape, will enable him to pull that particular part of the garment free from the others, thus allowing him to escape possible death or probable injury.

## IMPROVING CRANE CONDITIONS.

The craneman, in the average steel plant is in a position where it is difficult for him to be comfortable under adverse weather conditions, yet he must be ever on the alert in handling loads lest he cause damage or accident through overtraveling his mark, or false spotting of a load.

But is during the cold winter months that the craneman has the hardest time keeping on the watch. His work is such that he can not move around and keep himself warm—



he can't leave his post and go to one of the salamanders or other heat sources and warm, because the need for a crane arises without notice, and the man must be on the job all the time.

To eliminate these difficulties in crane operation, the Cutler-Hammer Manufacturing Company, Milwaukee, has brought out a type of electrical crane cab heater which makes it possible to regulate the temperature of the crane cab; and keeps the craneman at a temperature where he is able to do his work without being bundled in a lot of extra clothing—to render him slow and uncertain in his movements. The heater, as shown by the illustration, consists of standardized elements or resistor sections, with standard dimensions  $3/16 \times 1\frac{1}{2} \times 23\frac{3}{4}$  inches. The resistor is insulated and surrounded by mica within the steel jacket, eliminating even the remotest chance of grounding, and making the element absolutely safe for use in any crane. As many of these standard units may be used as are found necessary to keep the floor of the cab at the temperature desired. The shape of these resistors makes it possible to locate them in any convenient portion of the cab, taking none of the valuable operating space, yet warming the cab comfortably at slight current expense.



# NEWS OF THE PLANTS

The eleventh annual convention of the Association of Iron & Steel Electrical Engineers will be held in Philadelphia September 10 to 14 inclusive.

Wade A. Taylor, president of the Basic Iron Company, Niles, Ohio, a subsidiary of the DeForest Sheet & Tin Plate Company of the same place, is authority for the announcement covering the purchase of additional acreage near the Sheet & Tin Plate plant upon which the Basic company plans to erect a steel mill to serve the needs of the parent organization—at present amounting to about 80,000 tons of raw material per year.

The New York City office of the Titanium Alloy Manufacturing Company, formerly located at 15 Wall Street, has been moved to the City Investing Building, 165 Broadway.

The March meeting of the Association of Iron & Steel Electrical Engineers, Pittsburgh section, will be held at the Fort Pitt Hotel on Saturday, March 17th, beginning with a dinner at 6:00 p. m. and following with a series of talks at eight o'clock under the auspices of the electrical Development Committee, Stewart Coey, chairman.

## SIMPLIFYING ELECTRIC MOTOR DRIVES.

The application of electric motor drives to steel mill machinery formerly operated by steam engines is greatly facilitated by the use of silent chain drives. The dismantling of the steam plant, with the consequent disturbance of the bearings aligned for helical gears, does not affect the chain. This does not require the absolute hair line center to center adjustment of driver and driven, thus making correct alignment ample for the best operating results. Rigid centers are unnecessary, as the length of the drive can be adapted to the operating conditions. Short centers are available, and protective casings, which also exclude dust and permit running the drive in oil, make Safety First for the workmen a reality. Descriptive literature on chain drives furnished by the Link-Belt Company, Chicago.

Spring meeting of the American Chemical Society will be held in Kansas City, April 10-14. The programme follows:

Tuesday night, April 10, council meeting. Wednesday morning, April 11, opening session. Wednesday afternoon, April 11, opening session, continued or section meetings. Wednesday night, April 11, smoker. Thursday morning, April 12, section meetings. Thursday afternoon, April 12, section meetings. Thursday night, April 12, banquet, or open. Friday morning, April 13, section meetings. Friday afternoon, April 13, excursions. Friday night, April 13, banquet, or open. Saturday morning, April 14, excursions.

The Wm. B. Scaife & Sons Company, manufacturers of high pressure tanks and other plate and tank work, has moved its headquarters from 221 First Avenue, Pittsburgh, to the First National Bank Building, the change being effective March First.

According to Consul A. A. Williamson, Dairen, the proposed establishment of the Anshanchan steel works will be begun the next fiscal year. The Government steel works, at Edamitsu, will serve as consulting experts on the new

work, which will include two blast furnaces, with an annual pig capacity of about 150,000 tons. Plans and estimates are under preparation at the company's general offices, Anshanchan, Manchuria, China.

The Bethlehem Steel Company announces the purchase of the Lehigh Coke Company, with assumption of active management of the plant at Didier, Pa.,

The March meeting of the Philadelphia section of the Association of Iron & Steel Electrical Engineers will be held on the evening Saturday, March 3rd. C. T. Henderson, of the Cutler Hammer Manufacturing Company, Milwaukee, Wis., will be the speaker.

Plans have been filed for the new 50 x 100 foot foundry of A. Allan & Son, manufacturer of rolling mill bearing metals. This factory will be erected at South Fifth and Borgen Streets, Harrison, N. J., at a cost of \$15,300.

New interests are largely represented in the Wellman-Seaver-Morgan Company, Cleveland, as is indicated by the annual election of directors on February 20, when seven new directors were elected and only four of the old board were retained. The new directors are Franklin B. Richards, T. E. Borton and E. H. Whitlock, Cleveland; F. A. Seiberling, president Goodyear Tire & Rubber Company; Francis Seiberling and J. W. Chamberlain, Akron, and F. E. Myers, Ashland. The old directors re-elected are S. T. Wellman, W. P. Cowell, F. E. Hewitt and S. H. Pitkin.

The Bethlehem Steel Company broke three production records in January, according to an announcement by President E. G. Grace. In Mill No. 2 the 12-inch department produced 2063 tons, an increase of 196 tons over the best previous record; the 10-inch department made 1385 tons, bettering its previous mark by 252 tons; while the iron foundry exceeded its former mark of 6854 tons, making 7031 tons during the month.

## STEEL MANUFACTURE IN SOUTH CHINA.

A critical situation has been reached in the production of pig iron and the manufacture of steel and general steel products in South China, and the indications are that in the next few months there will be some important developments. Negotiations have been undertaken by various Japanese interests looking toward the acquiring of certain mining rights in South China and for the inauguration of a steel-making plant in or near Hongkong for serving the South China trade, especially in the line of rolled iron and steel plates not exceeding half an inch in thickness, for which there is a strong demand in this market and which can be manufactured in a plant of comparatively small cost.

A concern, the Hongkong Steel Foundry Co., (Ltd.), was organized five years ago for the purpose of making steel ingots or molds by a secret process from scrap steel, or, if the demand justified, from crude iron ore or pig iron says Consul General George E. Anderson, Hongkong. The company has slowly developed its business until it is now operating two double sets of four furnaces each but continues to use only scrap steel and pig. Its object, as indicated in its report, has been the development of a steel-manufacturing plant



to handle ore deposits in South China. With a view to such development the company has an option on several hundred acres in the Waichow district of Kwangtung Province and has plans for a complete plant, including railway and other transportation service to and from Hongkong and Canton. The sanction of the Chinese authorities only is now awaited for the advancement of the undertaking. However, outside capital is needed, and because of general business as well as war conditions it seems likely that the capital must come either from Japan or from the United States.

There seems to be no question that there is an exceptional opportunity for the investment of American capital in such

an undertaking, for the local demand for the output is so strong and material ordered from Europe or the United States is so slow arriving that the concern now in the field has much more than it can do. Apparently the cost of manufacture here even under present conditions can compare favorably with costs in Europe and the United States, while the advantage of freights under present conditions is in itself great enough to overcome many difficulties. The advance in development of the iron-working industry in South China is of the greatest importance industrially and otherwise and much of the prosperity of this portion of China in the future hinges upon it.

## RECENT PATENTS

The following patents are reported expressly for THE BLAST FURNACE AND STEEL PLANT, from the Patent Law Offices of Norman T. Whitaker, of Legal Building, Washington, D. C., (opposite U. S. Patent Office,) from whom copies of any one of the patents may be obtained by sending fifteen cents in stamps.

Patent No. 1,211,545 on the manufacture of steel was recently issued to Godfrey John Boyle, of Chetwynd, West Riding, England. The gist of the invention is substantially as follows: The process of purifying steel that has been normally finished in a steel making, refining or melting furnace and transferred to a receptacle so as to form therein a deep bath of molten metal preparatory to casting, which consists in causing electric current of large amperage to flow substantially through the whole depth of the molten metal and produce at the bottom thereof a small localized center of intense heat, maintaining the current to enable impurities to separate from the molten metal and rise to the surface thereof and afterward running off the purified metal from the bottom of the receptacle.

An apparatus for treating steel ingots has just been invented by Edward J. Flynn, Jr., of Woodlawn, Pa., which is patented as No. 1,212,470. Mr. Flynn claims among other features: An apparatus for the purpose set forth comprising a soaking pit having its bottom provided with upwardly extending supporting portions and each side wall with an inwardly extending abutment, said supporting portions adapted to contact with the inner corners of a pair of opposed ingots and each abutment adapted to contact with the outer side of each ingot of said opposed ingots for maintaining these latter in an upright position at each side of the center of the pit and spaced from said sides and bottom to obtain an equal distribution of heat around the ingots.

Edward H. Schwartz, of Chicago, Ill., was recently issued Patent No. 1,215,065 on the process of deoxidizing and refining ferrous metals. Inventor claims among other features: The process of deoxidizing and refining herein specified ferrous metals to obtain a product of relatively high carbon content, which consists in mixing with the metal in solid condition to be treated a manganese-containing alloy, and melting the mixture in the presence of carbonaceous material.

Patent No. 1,214,903 on a fuse was invented and issued to Louis W. Downes and Ralph Clifton Patton, of Providence, R. I. The gist of the invention is as follows: An electric fuse comprising of fuse link, a link inclosing casing, end closures therefor, and means including a sleeve portion on the casing end and a sleeve portion on the inner side of the casing end providing between them an extended cooling area over which the escaping gas generated within the casing must pass. This patent has been assigned to D & W Fuse Company, of Providence, R. I., a Corporation of Rhode Island.

A patent on Alloy Roll-steel has just been issued to Frank D. Taggart, of Wyomissing, Pa. Inventor claims the improved alloy roll-steel described, composed mainly of

iron, with percentages of carbon between 1.25 and 2.50, of chromium between 1.50 and 3.00, and of vanadium approximately .25; the minor elements present not exceeding one per cent.

A welding composition has just been invented by John A. Hope, of Montreal, Quebec, Canada, which is patented as No. 1,209,841. The gist of the invention is as follows: A high-speed steel and low carbon iron welding composition consisting of 80 per cent ferro-manganese, 60 parts; 50 per cent ferro-silicon, 20 parts; and burnt borax 20 parts. A high-speed steel and low carbon iron welding composition consisting of ferro-manganese, ferro-silicon and burnt borax.

Patent No. 1,215,672 on the process for treating metalliferous ores was recently issued to Richard Lewis Lloyd, of New York, N. Y., and was assigned to Dwight & Lloyd Metallurgical Company, of New York, a Corporation of New Jersey.

Fred E. Kling, of Youngstown, Ohio, was recently issued a patent on filtering medium for cleaning furnace-gases, which is as follows: A filtering medium for mechanically extracting dust from hot furnaces-gases consisting of a matted body of steel threads. A filtering medium for mechanical extracting dust from hot furnace gases consisting of a body of steel wool. Inventor has assigned one-half to Luther B. Weidlein.

The following patents are reported expressly for THE BLAST FURNACE AND STEEL PLANT by E. G. Siggers, patent attorney, Suite No. 31 N. U. Building, D. C., from whom copies of any one of the patents may be obtained by sending fifteen cents in stamps.

Sherwood S. Knight, Berkeley, Cal., has invented improvements in process of making steel and iron, No. 1,213,806, dated January 23, 1917. This invention is a method of making iron and steel of very high grades wholly or largely from cheap inferior, cold raw material. It consists, first, in charging directly onto the bottom a layer of ferrous material low in carbon to the extent of approximately 10 per cent to 20 per cent by weight of the entire charge, completely covering the bottom of the furnace; second, heating this ferrous material sufficiently to cause it to become a pasty mass third, charging non-ferrous material containing free carbon, and subsequently charging a fluxing material and ferrous material; and fourth, finishing and drawing off the product.

David A. Clark, of Baltimore, Md., has invented improvements in metal-rolling machine, No. 1,212,325, dated January 16, 1917. This invention relates to the art of metal rolling, and comprehends certain new and useful improvements in machines of the concave and roll type for shaping iron or steel. The machine includes a concave, a revoluble carrier mounted in spaced relation to the concave, and formed in its periphery with a longitudinally extending recess, a pair of work supporting rollers journaled in said recess, and anti-friction elements mounted in said recess and engaging said rollers.

# Steel Plant Incorporations and Construction

**Louisville, Ky.** — W. Gwilym Owen, 2161 Sherwood avenue, has plans for the establishment of a steel plant here, and to this end has secured a 1500-acre site on the lower Ohio river, below here, which is already traversed by three rail-ways, and which assures adequate rail transportation to the mill's ultimate product, in addition to the water facilities offered by the river.

**Clinton, Iowa.**—H. W. Seaman, presi- dent of the American Wire Fabrics Com- pany, is pushing plans looking toward the establishment of a steel plant here, to include by-product coke ovens, a blast furnace, and an open hearth steel plant and finishing mills for the manufacture of wire and wire products. The plant will have river transportation, as well as being located in the center of a large district which will absorb the major por- tion of the mill's products.

**Pittsburgh, Pa.** — The Heppenstall Forge & Knife Company, 47th and Hat- field streets, plans to install a six-ton Heroult electric furnace at its plant here, and has retained the services of Barton R. Shover, consulting engineer, Diamond Bank Building, as consulting engineer on the installation and power problems con- nected with the furnace.

**Wheeling, W. Va.**—The Wheeling Steel & Iron Company has voted to increase its capital stock from \$7,500,000 to \$10,- 000,000.

**Carnegie, Pa.** — The Union Electric Steel Company, word of whose incorpora- tion was carried in these columns at the time of the formation of the com- pany, plans to be in shape to produce high grade alloy steels in the six-ton Heroult furnace already installed, and is planning to install a second unit of like capacity as soon as it can be secured.

**Philadelphia, Pa.**—The Midvale Steel Company is taking bids for the con- struction of a one-story steel and con- crete addition, 65 x 79 feet, to its plant at Nicetown.

**Murphysboro, Ill.** — J. W. Harrison, formerly of the National Car Coupler Company, Attica, Ind., will erect an open hearth steel foundry here for the opera- tion of which the Harrison Steel Cast- ings Company, Inc., has been formed, with a capital of \$300,000. It is expected that the plant will be in operation by Sep- tember 1 of this year. Two steel and

brick buildings are to be erected, one a foundry building, 180 x 260 ft., and the other a cleaning room, 140 x 160 ft., with an additional building for the sand blast department. The plant will have two 15-ton open-hearth furnaces designed for the use of either oil or powdered coal. The foundry building will be spanned by one 25-ton and one 10-ton traveling crane, and the cleaning room by one 10-ton crane. The officers of the company are J. W. Harrison, president; R. J. Harrison, vice-president, and G. W. Har- rison, secretary and treasurer. The com- pany will have a Chicago office at 522 McCormick building.

**Cincinnati, Ohio.**—The Cincinnati Iron & Steel Company has plans for further additions to its plant at Fifth and Bay- miller streets. The latest plans are for two warehouse buildings, 100 x 200 ft., one story, of steel construction. Travel- ing cranes will be installed in both build- ings. James I. Stephenson is president.

**Newport, Ky.**—The Newport Rolling Mill Company has commissioned Tietig & Lee, architects, to prepare plans for a 50 x 200 foot steel mill construction addi- tion to the machine and blacksmith shops of the company.

**New Albany, Ind.** — The Ohio Falls Iron Company is installing a nine-inch Belgian roll train and otherwise adding considerably to its rolling capacity.

**Savannah, Ga.** — The United Furnace Company has been incorporated here for \$50,000 by John G. Struck and Otto Van Campen.

**New York City.**—The Upson-Walton Company, 291 Broadway, manufacturer of wire rope and cables, with plant at Cleveland, has filed plans for its pro- posed plant at 462-4 Riverside Avenue, Newark, N. J. The structure will be two-stories, 54 x 148 ft., estimated to cost \$18,000.

**Rahway, N. J.**—The Steel Equipment Corporation is remodeling the former plant of the Rahway Steel Works, near the Perth Amboy junction of the Penn- sylvania Railroad, to be used as a manu- facturing plant.

**Worcester, Mass.**—The American Steel & Wire Company is building an ad- dition to one of its buildings on Milbury Street to be used as a machine shop. It will be 20 x 100 ft., two stories.

**Trenton, N. J.** — The John A. Roeb- ling's Sons Company, manufacturer of wire and wire rope, will build two addi- tions to its plant at Canal and Elmer streets. The structures will be of brick and steel, each graduated in height from one to three stories, 95 x 594 ft., and 89 x 308 ft., to cost \$135,000 and \$120,000 re- spectively.

**Pittsburgh, Pa.**—The Standard Seam- less Tube Company has filed notice of an increase in its capital stock from \$1,- 200,000 to \$1,500,000.

## IRON AND STEEL QUOTATIONS COMPARED WITH PRICES OF A MONTH AGO

### PIG IRON.

| Pittsburgh*—          | January 21     | February 22    |
|-----------------------|----------------|----------------|
| Bessemer .....        | 35.95          | 35.95@ 36.95   |
| Basic .....           | 30.95@ 31.95   | 30.95@ 31.95   |
| No. 2 foundry ...     | 31.95@ 32.95   | 33.95@ 36.95   |
| Malleable .....       | 30.95          | 31.95@ 32.95   |
| Gray forge .....      | 29.95          | 31.95@ 32.95   |
| Ferro-silicon, 50% .. | 100.00@ 120.00 | 225.00@ 250.00 |
| Ferro-silicon, 10% .. | 40.00@ 42.00   | 46.00@ 47.00   |
| Ferro-mang., 80% ..   | 170.00@ 175.00 | 175.00@ 185.00 |
| Spiegelisen, 20% ..   | 50.00@ 55.00   | 65.00@ 70.00   |

\* Pig iron prices quoted here are at Pitts- burgh, with freight rate from Valleys to Pittsburgh, 95 cents added.

### Virginia Furnaces—

|                   |              |              |
|-------------------|--------------|--------------|
| Basic .....       | 27.25        | 27.75        |
| No. 2X .....      | 27.25@ 28.25 | 29.50@ 30.00 |
| No. 2 plain ..... | 27.00@ 28.00 | 29.00@ 29.50 |
| Gray forge .....  | 25.50@ 26.00 | 27.00@ 28.00 |

### Birmingham—

|                    |              |              |
|--------------------|--------------|--------------|
| No. 2 foundry .... | 24.00@ 25.00 | 23.50@ 25.00 |
| No. 3 foundry .... | 23.50@ 24.50 | 23.00@ 24.50 |
| Gray forge .....   | 23.00@ 24.00 | 22.50@ 24.00 |

### Philadelphia (del.)—

|                     |              |              |
|---------------------|--------------|--------------|
| No. 2X foundry .... | 30.00@ 31.00 | 32.00@ 33.00 |
| No. 2 plain .....   | 29.50@ 30.50 | 31.50@ 32.50 |
| Basic .....         | 30.00        | 30.50@ 31.00 |
| Gray forge .....    | 28.25@ 28.75 | 29.75@ 30.75 |

### Chicago (at fur.)—

|                    |              |       |
|--------------------|--------------|-------|
| No. 2 foundry .... | 31.00@ 32.00 | 33.00 |
| Malleable .....    | 31.00@ 32.00 | 33.00 |
| Basic .....        | 31.00        | 33.00 |

### Cincinnati (del.)—

|                       |       |       |
|-----------------------|-------|-------|
| Northern No. 2 rdy .. | 31.25 | 32.25 |
| Basic .....           | 31.25 | 34.25 |
| Nor. malleable ...    | 31.25 | 34.25 |

### STEEL.

#### Tons of 2,240 lbs.,

| at Pittsburgh.         |              |              |
|------------------------|--------------|--------------|
| Bessemer billets ..    | 65.00@ 70.00 | 65.00@ 70.00 |
| Open hearth billets .. | 65.00@ 70.00 | 65.00@ 70.00 |
| Forging billets ...    | 80.00@ 85.00 | 80.00@ 85.00 |
| Sheet and tin bars ..  | 65.00@ 70.00 | 65.00@ 70.00 |
| Wire rods .....        | 75.00        | 75.00@ 80.00 |

### FINISHED PRODUCT.

#### Tons of 2,000 lbs.,

| at Pittsburgh.       |               |                |
|----------------------|---------------|----------------|
| Skelp, grooved ...   | 57.00         | 65.00          |
| Skelp, sheared ....  | 60.00         | 70.00          |
| Sheets, No. 28 ....  | 90.00@ 100.00 | 95.00@ 100.00  |
| Galvanized sheets .. | 125.00        | 125.00@ 140.00 |
| Shapes .....         | 70.00@ 80.00  | 70.00@ 80.00   |
| Plates .....         | 80.00         | 75.00@ 80.00   |
| Hoops .....          | 70.00         | 75.00          |
| Rails .....          | 60.00         | 65.00          |
| Steel bars .....     | 60.00@ 62.00  | 60.00@ 65.00   |
| Iron bars .....      | 65.00         | 65.00@ 68.00   |

#### Per lb. on large orders:

|                     |            |            |
|---------------------|------------|------------|
| Tin plate .....     | 7.00@ 8.00 | 7.50@ 8.00 |
| Plain wire .....    | 2.95       | 3.05       |
| Galvanized wire ... | 3.05       | 3.05       |
| Wire nails .....    | 3.00       | 3.00       |
| Galvanized nails .. | 4.00       | 4.00       |